

Table 5-3
Water Quality Impaired Segments

River	River Segment	Size	Impairment Cause
Beaver Brook	New Hampshire state line, Dracut to confluence with Merrimack River, Lowell	4.8 Miles	(Debris/Floatables/Trash*);(Physical substrate habitat alternations*); Aquatic Macroinvertebrate Bioassessment; Escherichia coli; Taste and Odor; Turbidity
Concord River	From the confluence of the Assabet and Sudbury rivers, Concord to the Billerica Water Supply intake, Billerica.	10.4 Miles	Eurasian Water Milfoil, Myriophyllum Spicatum*); (Non-Native Aquatic Plants*); Fecal Coliform; Mercury in Fish Tissue; Phosphorus (Total)
Concord River	From the Billerica Water Supply intake, Billerica to Rogers Street bridge, Lowell.	5.1 Miles	Phosphorus (Total); Mercury in Fish Tissue; (Non-Native Aquatic Plants*) (Eurasian Water Milfoil, Myriophyllum spicatum*)
Concord River	From the Rogers Street bridge, Lowell to the confluence with the Merrimack River, Lowell.	0.9 Miles	Mercury in Fish Tissue; Phosphorus (Total); Fecal Coliform; Excess Algal Growth; (Debris/Floatables/Trash*)
Merrimack River	State line at Hudson, NH/Tyngsborough, MA to Pawtucket Dam, Lowell.	9 Miles	Fecal Coliform; Mercury in Fish Tissue
Merrimack River	Pawtucket Dam, Lowell to Lowell Regional Wastewater Utilities outfall at Duck Island, Lowell.	3.2 Miles	Phosphorus (Total); Fecal Coliform; (Low flow alterations*); Mercury in Fish Tissue
Merrimack River	Lowell Regional Wastewater Utilities outfall at Duck Island, Lowell to Essex Dam, Lawrence.	8.8 Miles	Fecal Coliform; Mercury in Fish Tissue; PCD in Fish Tissue; Phosphorus (Total)
Merrimack River	Essex Dam, Lawrence to confluence with Little River, Haverhill.	10 Miles	PCB in Fish Tissue; Phosphorus (Total); Fecal Coliform
Merrimack River	Confluence Little River, Haverhill to confluence Indian River, West Newbury/Amesbury.	1.83 Square Miles	Fecal Coliform; PCB in Fish Tissue
Merrimack River	Confluence Indian River, West Newbury/Amesbury to mouth at Atlantic Ocean, Newburyport/Salisbury (includes Back River, Salisbury).	4.5 Square Miles	PCB in Fish Tissue; Fecal Coliform

*TMDL not required (Non-Pollutant)

Source: Massachusetts Section 303(d) List of Waters (2012)

5.5 Existing Water Quality - Merrimack River Watershed Assessment

General

A comprehensive watershed-based study was undertaken by the CSO communities on the Merrimack River starting in 2002. The effort was jointly funded by the CSO communities and the federal government, through the United States Army Corps of Engineers (USACE) New England District. The five local-community sponsors are Manchester and Nashua, New Hampshire; Lowell and Lowell, Massachusetts; and the Greater Lawrence Sanitary District (GLSD), Massachusetts. Collectively, these communities formed the Merrimack River Basin CSO Coalition (MRBC).

The overall purpose of the watershed assessment was to develop a comprehensive watershed management plan for the Merrimack River watershed. The plan could be used to guide investments in local environmental resources and infrastructure, with the goal of achieving water quality and flow conditions to support uses such as drinking water supply, recreation, fisheries and aquatic life support.

Water quality and streamflow data were collected for this study and used in the calibration and validation of water quality and hydrologic/hydraulic models. The water quality models were used to determine whether segments of the mainstem of the Merrimack River are likely to meet state water quality standards with discharge improvements.

Sampling Program

The monitoring area encompassed the mainstem of the Merrimack River from Concord, New Hampshire to its estuary in Newburyport, Massachusetts, and also included the mouths of eleven major tributaries adjoining the mainstem. Forty-two sampling locations were strategically located in-stream to measure streamflow and concentration of pollutants such as bacteria and nutrients. Additionally, numerous stormdrain outfalls and combined sewer overflow (CSO) outfalls were sampled during wet-weather events to monitor contributing pollutant loads from urbanized areas.

From 2003–2005, three dry-weather surveys and four wet-weather surveys were conducted. A continuous survey of dissolved oxygen and temperature was also conducted at two locations for a one-month period during low-flow conditions in August and September 2003.

The following conclusions were drawn from the water-quality surveys:

- The mainstem of the Merrimack River from Manchester to the Atlantic Ocean is impaired with respect to bacteria standards, although many reaches exhibit satisfactory bacteria levels during dry weather.
- Many of the tributaries are impaired with respect to bacteria standards during wet weather, as measured upstream of combined sewer outfalls.
- The mainstem of the Merrimack River from Manchester to the Atlantic Ocean is not impaired with respect to dissolved oxygen standards. Measured and simulated concentrations of dissolved oxygen were always well above the regulatory threshold of 5 mg/l.
- While currently there are no regulatory requirements for nutrient levels in the river waters, levels of nutrients (phosphorus and nitrogen) in rivers can be indicative of the likelihood of

excessive in-stream organic production, which can deplete oxygen levels in the water and degrade aquatic habitat quality. Mainstem concentrations of nitrogen and phosphorus exhibited a wide range that is generally thought to be acceptable.

- Levels of chlorophyll-a, another indicator of organic productivity in the water, were generally not excessive in the New Hampshire reaches of the river. Levels in the mainstem downstream of Lowell ranged as high as 42 µg/L under 7Q10 conditions. Despite these high levels of chlorophyll-a, no impairment of dissolved oxygen was found, indicating that the river can support high levels of algae growth.

Receiving Water Quality Evaluation

One of the objectives of the Merrimack River Watershed Assessment was to complete a comprehensive analysis, using computer models, of the impacts of CSO discharges and point and non-point stormwater discharges to assess the incremental benefits that would be achieved by the complete elimination of all CSO discharges along the Merrimack River.

Model Development

A suite of hydrologic, hydraulic, and water quality models were developed as tools to assist in evaluating and comparing watershed management strategies and in prioritizing potential improvements in the watershed. The goals of the modeling effort were to:

- Simulate the generation of pollutant loads (primarily bacteria and nutrients) throughout the watershed, both from point sources and nonpoint sources.
- Simulate the water quality and flow regimes in the mainstem Merrimack River under dry weather and wet weather conditions.
- Simulate the dynamic nature of storm events as well as seasonal patterns and their effect on water quality and hydraulic conditions in the mainstem Merrimack River.

These goals were achieved by combining the strengths of several different public domain models. Existing models of combined sewer systems developed in USEPA Storm-Water Management Model (SWMM) and Modeling of Urban Sewers (MOUSE) for each of the five major CSO communities in the basin were incorporated. Fortran (HSPF) was used to model the remainder of the watershed hydrology, including all major tributaries, as well as non-point source loads for the basin. The CSO and HSPF flow inputs were entered into the EXTRAN block of the SWMM model, which simulated the hydraulic routing and dynamics of the mainstem Merrimack River. The Water Quality Simulation Program (WASP) was used to simulate dynamic concentrations of bacteria, nutrients, dissolved oxygen, chlorophyll-a, and BOD in the river. Prior to being used in a predictive mode, the models were compared to measured data to first calibrate and then verify that they were accurately simulating real conditions in the river.

Model Simulations

Using the hydrologic and hydraulic models, a series of discharge abatement strategies were evaluated throughout the watershed to determine the water quality benefits and river improvements that could be achieved by these options.

Figure 5-4 shows a summary of the compliance status for bacteria along the Merrimack River under the various options. This figure uses the past bacteria standard for Massachusetts, which was a geometric mean of all daily fecal coliform values over the 180-day simulation period must be less than 200 org/100ml and no more than 10 percent of all daily fecal coliform values over the 180-day simulation period may exceed 400 org/100ml.

The status of each of the 140 river segments represented in the simulation model is shown as “Baseline: Existing Conditions”. It illustrates that the entire reach from Lowell to the ocean exceeded bacteria limits under the existing conditions at the time of the report (2006). Under current conditions, “Phase I CSO” (as Phase I controls have been implemented by all CSO communities along the river), a portion of the river, downstream of Lowell and all the way to the ocean, should be in compliance with bacteria standards (in Massachusetts) and should support primary and secondary contact recreation under most conditions.

The following conclusions were drawn from the analysis of the alternative discharge abatement strategies:

- An alternative strategy is to reduce nonpoint source control to reasonable levels, as defined by approximately 20 percent reduction of all runoff concentrations and reduction of background concentrations in highly polluted tributaries to 5,000 organisms/100ml (still well above standard). This is shown in “Nonpoint Source Reductions Only”. This strategy will offer significant improvements in compliance with bacteria standards upstream of Lowell but does not significantly change the downstream compliance status.
- Full separation of combined sewers, in all communities, shown as “Theoretical 100% CSO” would offer very little improvement in river water quality downstream of Lowell. This condition exists because overflow events, taken together, occur for a very small percentage of the time in any given year. The remainder of the time, the river system is dominated by stormwater and background concentrations that often exceed bacteria standards.
- Long-Term phased CSO abatement programs (including partial separation, storage, increased treatment capacity, etc.), beyond the Phase 1 programs, offer very little additional improvement in compliance when compared to Phase I abatement alone for the river reaches downstream of Lowell. As shown in “Phase II CSO Programs”, there are very few appreciable instream benefits of Long-Term CSO control plans beyond the Phase I programs (that are almost completed). The impact of future Phase II CSO programs was also evaluated coupled with nonpoint source abatement. However, while the future Phase II long-term alternatives will reduce the occurrence of very high bacteria levels in the river, these occur during a total of just a few days during each year. Again, stormwater dominates as an impact to the water quality compliance status of the river during rainfall events based on this analysis.

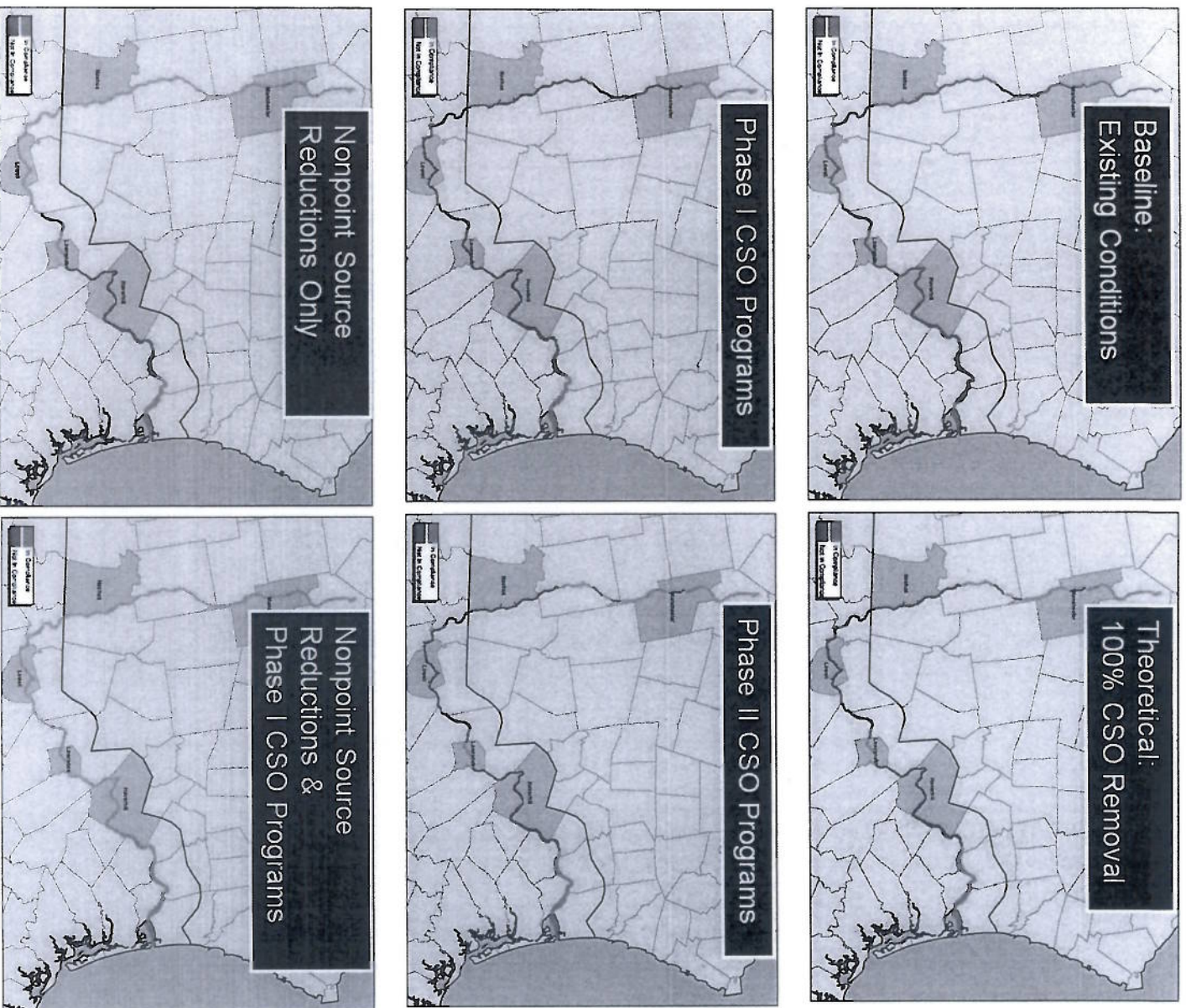


Figure 5-4
Compliance Summary for Watershed-Wide Abatement

- The analysis does show that Nonpoint Source (NPS) controls coupled with Phase I CSO controls implemented by the Merrimack River CSO communities will be sufficient to achieve compliance as shown in “Nonpoint Source Reductions & Phase I CSO Programs”. In fact, the implementation of the nonpoint source reductions described above would actually increase the effectiveness of Phase I CSO controls by bringing the river closer to compliance and closing the gap that CSO abatement would need to bridge. Model results suggest that under normal hydrologic conditions, the river would be fully compliant with bacteria standards with the suggested nonpoint source reductions and Phase I CSO abatement. During abnormally dry and wet years, there may still be small isolated reaches that do not fully comply.

By far, the greatest value in abatement dollars can be realized with nonpoint source abatement and Phase I CSO controls. Potential Phase II CSO measures offer much lower value. In this case, value is measured in terms of river miles or days of compliance that can be achieved for every million dollars spent. Study results suggest that a balanced watershed management plan that includes modest CSO abatement coupled with reasonable levels of nonpoint source reduction should form the basis of watershed management decisions in the Merrimack Basin.

Results also suggest that such a balanced strategy would be eight times more cost-effective than full CSO separation using this same metric. In addition to being more cost-effective, the balanced approach would offer significantly more benefits than Phase II CSO abatement alone, and would result in a river that would comply with water quality standards under most conditions. Lowell still is proposing CSO work beyond Phase I.

5.6 Summary

The principal receiving water for Lowell's CSO discharges is the Merrimack River. CSO discharges to the Concord River and Beaver Brook do not impact the designated uses of the receiving waters as the affected portions downstream of the discharges are shorter segments that are not readily accessible for recreational or fisheries uses.

CSO discharges are point source discharges and subject to the requirements of USEPA's CSO Policy, the state's CSO Control Strategy, and the Massachusetts WQS. The Merrimack River through Lowell is on the 303(d) list of impaired waters based on concentrations of bacteria in the waterway. The city's CSO discharges do not meet the water quality criteria for Class B and SB waters for bacteria but the river will likely continue to exceed the bacteria standard, even with full elimination of CSO discharges, because of background point and non-point source stormwater discharges. It is important to note that there are no designated swimming areas along the river, downstream of Lowell.

The river below Lowell to the ocean at Salisbury/Newburyport has a multitude of uses. The river supports both fresh water fisheries and anadromous fish. Though no public swimming beaches exist on the Merrimack River in this segment, the river is used for boating and canoeing. A shellfish resource exists on the Merrimack River below the I-95 bridge in Salisbury. This shellfish area is conditionally harvested but may never be fully reopened unconditionally because of the upstream bacteria contamination and the proximity of the Newburyport and Amesbury WWTP discharges, regardless of Lowell's CSO discharges.

Lowell's CSO planning is complicated by several factors, as discussed above, including a regulatory strategy that differentiates between pollutant sources within the watershed instead of a watershed-based plan. TMDLs, including a comprehensive assessment of river uses, have not yet been formally

approved for the Merrimack River. Because of these complicating factors, the specific applicability of these CSO policies (and their intended water quality goals) to the city is unclear and appears to warrant a reclassification of the river. What is clear is that the city must comply with EPA's Nine Minimum Controls, as these are the technology-based control requirements applicable to all CSO communities.

Beyond the nine minimum controls, the application of the CSO policies is complicated by the following factors:

- No final TMDL has been approved for the Merrimack River. Although control of CSOs in Lowell could lead to some improved water quality downstream of the city, it has not been reasonably demonstrated that CSO control alone would serve to protect existing or future uses, or that these uses can even be achieved given reasonable assumptions concerning the impact of nonpoint sources.
- There are four CSO communities on the main stem of the Merrimack upstream of Lowell, two in New Hampshire and two in Massachusetts. The CSO control planning and implementation for these communities continues. Lowell's approach to LTCP implementation should reflect the ongoing activities of these other communities so that reasonable level of use attainment is achieved concurrently on all segments of the Merrimack River.

In the following sections of this report, a range of CSO alternatives will be developed to identify the costs of incremental CSO discharge control. Discussion of these CSO alternative costs will be compared to the proposed incremental benefits of continuing to reduce Lowell's discharges both in volume and frequency, and the attainability of river uses.

The development of Lowell's long-term control plan should consider the needs and concerns of their residents, including both environmental and economic concerns, while considering the results of the Merrimack River Assessment study and its conclusions regarding the overall goal of meeting water quality standards, enhancing the attainability of river uses, and improving the quality of the environment.

Massachusetts WQS recognizes that full compliance with all Class B/SB criterion may be difficult or impossible for CSO impacted waters. However, the regulators provide several options for a temporary variance and permanent changes to designated received water uses (reclassification to BCSO or SBCSO). Given the existing conditions along the river, this may eventually be the appropriate approach for the city.

Section 6

Assessment of CSO Abatement Technologies

6.1 General

This section describes available CSO abatement technologies and assesses their applicability to achieve LRWWU's CSO control objectives. Many alternative strategies are available to control pollutants discharged from CSOs ranging from no action to complete separation of the combined sewer system into separate sanitary and stormwater systems. This assessment considers technologies presented in the EPA Long-Term CSO Control Plan guidance manual. The purpose of this assessment is to initially select appropriate technologies for further evaluation and comparison in later in the report.

6.2 Ongoing Implementation

LRWWU and the city of Lowell currently perform a comprehensive program of operations and maintenance activities designed to minimize receiving water impacts from CSOs. This includes implementation of the nine minimum controls, sewer inspection and sewer cleaning, sewer system rehabilitation, and progressive CSO station maintenance.

6.3 Screening of CSO Abatement Technologies

CSO abatement technologies were divided into five general categories:

- Quantity Source Control Measures
- Quality Source Control Measures
- Collection System Controls
- Storage Technologies
- Treatment Technologies.

Many of the source control measures and collection system controls are typical best management practices (BMPs) that are already performed by the city of Lowell. Most of these CSO control technologies were already discussed and incorporated into the Nine Minimum Control (NMC) Measures Report (April 1998, CDM). An overview of these controls is presented herein as part of the Long Term Plan evaluation process. Some of the BMPs are watershed/drainage basin type controls that are complemented by general public housekeeping efforts (i.e., litter control, hazardous waste collection, illegal dumping ordinances, etc.). Accordingly, a public information program regarding CSOs and the Long term Plan in Lowell is beneficial to the successful implementation of BMPs. Draft educational materials to inform the public about CSOs, receiving water impacts, and public involvement were included in the NMC report.

Each technology is described below and evaluated in general terms of effectiveness and feasibility in Lowell. Technologies that are infeasible for implementation in Lowell, or that offer no benefit to the CSO mitigation program were eliminated from further consideration. The remaining technologies are

Table 6-1
CSO Abatement Technologies Assessed

CSO Control Technology	Technology Not Widely Applicable or Appropriate	Continue Current Practice	Update/Initiate Practices	LTCP Technology
Quantity Source Controls				
Porous Pavement		X		
Flow Detention/Retention		X		
Area Drain and Roof Leader Disconnection		X		
Utilization of Previous Areas for Infiltration		X		
Catch Basin Modifications	X			
Quality Source Controls				
Air Pollution Reduction	X			
Solid Waste Management		X		
Fat, Oil, and Grease Control Programs (FOG)		X		
Street Sweeping		X		
Fertilizer/Pesticide Control		X		
Snow Removal and Deicing Practices		X		
Soil Erosion Control		X		
Commercial/Industrial Runoff Control		X		
Animal Waste Removal		X		
Catch Basin Cleaning		X		
Catch Basin Modifications - Hoods/Baffles		X		
Collection System Controls				
Existing System Management		X		
Regulator Modifications		X		
Sewer Cleaning/Flushing		X		
Sewer Separation				X
Infiltration/Inflow Control		X		
Polymer Injection	X			
Regulating Devices and Backwater Gates		X		
Remote Monitoring and Control/Flow Diversion		X		
Relocation of CSO Outfalls (Combine & relocate)	X			
Storage Facilities				
In-Line Storage				X
Off-Line Storage				X
Surface Storage	X			
Treatment Technologies				
Wastewater Treatment Plant Improvements				X
Screening		X		
Sedimentation		X		
Enhanced High-Rate Clarification				X
Chemical Flocculation	X			
Dissolved Air Flotation	X			
Swirl Concentrators	X			
Biological Treatment	X			
Filtration	X			
Disinfection				X

identified as NMC/BMP type controls or Long term CSO Control Plan alternatives in the narrative. Technologies identified as NMC measures may have already been addressed in the NMC report. Technologies that should be considered for Lowell's long term CSO mitigation program alternatives are evaluated further in later sections of this report.

Table 6-1 Lists the CSO abatement technologies considered for this report and identifies the results of the technology evaluation/screening. The following groups have identified the technologies:

- Technology Not Feasible. These technologies will not work effectively in Lowell or will not reduce the water quality impacts associated with CSOs.
- Continue Current Practice. These technologies are typical best management practices and were, for the most part, addressed in the Nine Minimum Controls report submitted in September 1996. These technologies will help to optimize system operations and minimize CSO discharges and impacts to the rivers.
- Update Practices. These technologies should be considered by the city to improve existing operations and minimize flows.
- LTCP Technology. These technologies are feasible structural controls that will reduce and/or eliminate Lowell's CSO discharges and impacts.

6.4 Source Control Measures

Source control techniques can be employed to either decrease the quantity of water entering the system or minimize certain pollutants from the waste stream at their source (quality control). Generally, source control techniques do not require significant structural improvements and thus, have minimal capital costs. However, these measures are labor intensive, and, therefore, have high operation and maintenance costs. The intent of implementing a source control measure is ultimately to help reduce or eliminate more capital intensive downstream (structural) CSO control facilities.

6.5 Quantity Control Measures

Quantity control measures are intended to reduce and/or eliminate portions of the wet weather flow generated in the basin tributary to the CSO regulator. Quantity control measures include the use of porous pavements, flow detention ponds, area drain and roof leader disconnection, the use of pervious area for infiltration, and catch basin modifications using flow retardation devices.

6.5.1 Porous Pavement

The quantity of runoff that enters a combined sewer system may be reduced or attenuated through porous pavement. Porous pavement is potentially more cost effective in new developments than existing paved areas because pavement removal is expensive and disruptive to traffic. It is unlikely that the use of porous pavement would be cost effective in Lowell since, for the most part, the areas surrounding the combined sewer system are densely developed. It would also take a significantly long period of time to regrade and pave impervious areas in order to achieve flow control.

LRWWU installed porous pavement and porous concrete in two locations at the Duck Island WWTF as a demonstration project. So far, the porous areas have performed well. Accordingly, porous pavement may be considered as a potential (limited) strategy to help reduce CSO discharges but it is not likely to

be the only solution. This strategy would be incorporated into the plan as part of a green infrastructures strategy to develop an integrated plan.

6.5.2 Flow Detention

Detention ponds in upstream areas of the tributary basin can be used to temporarily store stormwater runoff, attenuate flow peaks and minimize potential downstream treatment capacities. After the storms, collected water would drain back into the system and be conveyed to the WWTP for treatment.

The majority of the combined sewer system is densely developed, which restricts the capability to implement this technology as a system-wide strategy. There are several smaller areas (i.e., comprised of one or two streets) where a separate storm drain system enters (recombines with) the existing combined sewer system. However, these areas are too few and too small to consider for cost effective flow detention (as compared to downstream CSO facilities). In addition, there are several brooks and stream that enter the collection system where flow detention of the collected stormwater could be a benefit in Lowell but the area around this brooks and streams is fully developed. Additional studies are needed to identify whether flow detention would be effective locally.

LRWWU installed a flow retention pond at the Duck Island WWTF as a demonstration project. So far, the pond has performed well. Accordingly, detention ponds may be considered as a potential (limited) strategy to help reduce CSO discharges but it is not likely to be the only solution. This strategy would be incorporated into the plan as part of a green infrastructures strategy to develop an integrated plan.

Flow detention/retention is also considered for larger development in Lowell by the Engineering Department during subdivision reviews. In accordance with state stormwater policies, developers must attenuate the flow from their property. This will help to reduce stormwater runoff over time.

6.5.3 Area Drain and Roof Leader Disconnection

In urban areas, such as Lowell, roof leaders from gutters or roofs and area drains are often connected to the combined sewer system. Direct connection to the system avoids excessive surface runoff across properties to the catch basins or street drainage collection system. However, these direct inflow connections increase the peak flow rates during storm events by decreasing the time of concentration within the drainage basin.

During its sewer separation programs, LRWWU has actively investigated potential yard drain and roof leader connections to the sewer system as possible inflow sources that could be eliminated. This effort has elevated the effectiveness of the sewer separation program. As LRWWU separates additional portions of the combined sewer system in the city, the utility will continue the practice to disconnect these inflow sources.

However, as a system-wide solution to CSO reduction, this technology may not be cost effective when compared with the incremental costs required for downstream CSO controls. Therefore, disconnection of these inflow sources as an alternative to CSO treatment/storage technologies will not be considered further. However, the city should still attempt to remove inflow sources whenever opportunities arise, especially at large properties with substantial runoff.

6.5.4 Utilization of Pervious Areas for Infiltration

This technology in effect combines some of the aspects of the previous two strategies by attempting to maximize the use of pervious areas for infiltration. Various types of facilities include grassed swales, infiltration basins and subsurface leaching facilities. Generally, this type of control is more appropriate for new development or redevelopment where some significant area of well drained, pervious soils exist. Where possible, proposed flow detention ponds could be constructed with pervious soils on the bottom to take advantage of available infiltration rates.

This strategy is applied to new large development in the city. However, as a system-wide solution to CSO reduction, this technology may not be cost effective when compared with the incremental costs required for downstream CSO controls. In addition, the city is densely developed with no large areas for detention.

Infiltration technologies may be considered as a potential (limited) strategy to help reduce CSO discharges but it is not likely to be the only solution. This strategy would be incorporated into the plan as part of a green infrastructures strategy to develop an integrated plan.

6.5.5 Catch Basin Modifications

Modifications to existing catch basins can be made to reduce peak stormwater inflows to the combined sewer system. Catch basins within a drainage area can be retrofitted with devices, such as a vortex valve, that will retard the surface water runoff entering the sewer system. This device, however, can cause the catch basin and adjacent street area to flood. This is also a concern as street flooding can be a problem during the winter with ice and snow. Accordingly, the selection of the appropriate size vortex valve is important to limit the extent of street flooding. Typically, the selection of the appropriately sized vortex valve is made through a trial and error process.

Based on a preliminary review of the incremental cost of downstream CSO controls, the use of vortex valves to restrict peak inflows to the combined sewer system would not be cost effective in most areas of Lowell's combined sewer system. Accordingly, this alternative will not be considered further.

6.6 Quality Source Control Measures

Quality control measures help to reduce pollutant concentrations at sources in the tributary basins and improve stormwater runoff quality before it enters the combined sewer system. Most of these measures directly address source control before the pollutant is dissolved in the rainfall and/or conveyed to the catch basin. The final measure, catch basin cleaning, represents the last technology to retard the introduction of additional pollutants to the combined wastewater flow. The advantage of many of these technologies is that they can also have beneficial environmental effects in separated stormwater collection areas.

6.6.1 Air Pollution Reduction

Particulate matter in the atmosphere ultimately settles and becomes a source of stormwater runoff contamination. The "dustfall" is a result of both natural causes (fugitive dust from soils and pollen) and manmade processes (grinding and pulverizing processes, combustion, construction dust, etc.).

This source of pollution is not significant compared to other sources and therefore does not warrant further evaluation.

6.6.2 Solid Waste Management

Improper disposal of litter, including leaves, grass clippings, waste paper, wrappings, cigarettes, metal, glass, and paper containers on city streets, in parks and along vacant properties often results in these items entering the collection system and potentially being discharged to the receiving water. The floatable nature of these items can cause visible pollution.

This technology was discussed in the NMC report and the Notice of Intent for the MS4 Stormwater General Permit. The city has already implemented a number of city ordinances to control litter and manage solid waste. In addition, the city has a program to mark catch basins with signage to inform the public that the catch basin leads to a surface water as part of an education program to minimize litter in the street or inadvertent disposal of waste in catchbasins. Generally, in urban areas, it is not expected that further enhancements to existing solid waste management programs will completely control floatables. Accordingly, recommendations to improve current procedures and policies are not warranted in Lowell.

6.6.3 Fats, Oil, and Grease Control Programs

Fats, oil, and grease (FOG) are often improperly disposed of by pouring these items down the sink. FOG builds up in sewers over time and often causes blockages and reduces the capacity of the pipe to convey flow. EPA's August 2004 "Report to Congress on Impacts and Control of CSOs and SSOs," reports that 47-percent of sewer blockages can be attributed to grease buildup. These blockages account for nearly half of all sanitary sewer overflows (SSOs). The best way to prevent these blockages is to keep FOG from entering the sewer system.

Education programs about proper disposal of FOG can reduce the problems in the sewer system associated with FOG. At a minimum, restaurants should have and regularly maintain grease traps to remove the FOG. Grease traps slow the flow of wastewater and allow FOG to cool and float to the top, where it can be removed, so it does not get conveyed downstream in the sewer system.

Education programs can be used to inform residents and commercial establishments, such as restaurants, about the proper methods for disposal. The effectiveness of pollution prevention programs, such as educating owners about FOG, is highly dependent on individual actions. The effect of the education and removal of FOG cannot be quantified.

The city currently has a FOG program in-place, administered by its Board of Health. Though it is prudent practice, it will not be considered for further evaluation as a CSO control measure.

6.6.4 Street Sweeping

Street sweeping is a common practice in urban areas to improve the aesthetic environment by removing litter and debris from gutters. This practice can also improve the water quality of surface runoff by reducing the quantity of solids and floatables entering the combined sewer system. Street sweeping is performed using mechanical brooms or vacuum sweepers.

Lowell makes every effort to ensure all streets in the city are swept twice per year. All streets are swept in the spring and fall.

6.6.5 Fertilizer/Pesticide Control

The use of fertilizers and pesticides can increase the pollutant levels, primarily nutrients, in stormwater runoff. Controlling chemical use and storage can help reduce this pollutant loading.

However, effective control of these pollutant sources is difficult. In addition, CSO quality sampling results indicate that fertilizers and pesticides are not significant waste stream pollutants in Lowell's CSO discharges.

Through the NPDES Stormwater program, LRWWU and the city implement a public education program aimed at curtailing fertilizer/pesticide use. The city parks department is also aware of these impacts and attempts to limit is use of these items on public land.

However, since these parameters are not an apparent source of CSO pollution, additional control of fertilizers and pesticides as an overall drainage basin program will not be considered beyond current practices for the development of the LTCP.

6.6.6 Snow Removal and Deicing Practices

Salting roadways during the winter to reduce icing can increase surface runoff pollutant loads, particularly chloride concentrations. Improper storage of salt can also contribute to high chloride concentrations, especially if the salt is not covered or protected from rain. Generally salt is mixed with sand to reduce skidding on roadways. The sand can accumulate in catch basins and eventually enter the combined sewer system contributing to the solids loading in CSO discharges.

Lowell uses a synthetic salt mixture, which minimize the use of salt and uses no sand for deicing roads. Deicing practices will not be considered for further study as an alternative to minimize structural CSO facilities.

6.6.7 Soil Erosion Control

Construction sites contribute to sediment in surface runoff. The city currently enforces standards established by the state for Construction Site Drainage Permits for construction projects under the Massachusetts stormwater management policy and the city's NPDES Stormwater General Permit. Continued enforcement of these guidelines can maintain reduced suspended solids loadings to the receiving waters. Although soil erosion is not a significant source of CSO related pollution in Lowell, erosion and sediment control practices should continue to be enforced at all construction sites. Additional controls will not be considered for the development of the LTCP.

6.6.8 Commercial/Industrial Runoff Control

CSO pollutant discharge quality can be improved through the control of runoff from commercial and industrial establishments in the drainage area. Of particular concern are gas stations and other petrochemical establishments. Oil traps or permanent oil collection systems can be used to reduce the quantity of pollutants entering the system. Illegal dumping policies are enforced regularly by the city agencies such as the Highway, Police, Parks, Health, and Fire Departments. Additional controls will not be considered for the development of the LTCP.

6.6.9 Animal Waste Removal

Animal excrement is a source of stormwater pollution, especially nitrogen and pathogenic organisms (E. Coli is an indicator). Proper disposal of the animal waste could help reduce the bacteria and nutrient concentrations in the CSO discharges by eliminating one source of pollutants (nutrients were not noted as a concern by the regulatory agencies). It is expected that Lowell's current solid waste disposal, littering ordinances, and street sweeping programs are adequate to address this potential problem. In addition, the city has a public education program about pet waste as part of its NPDES Stormwater program. Because the impact of this pollution source is limited and future regulations

could address this problem if it becomes significant, this technology will not be considered further for CSO abatement.

6.6.10 Catch Basin Cleaning

Catch basins are installed in collection systems to collect and convey surface runoff to the sewer or drainage system. The basins are designed with a sump below the outlet pipe to capture sand, grit, and solids. Catch basins require periodic cleaning to remove the solids and floatables captured in the sump. The structures can be cleaned using a bucket or vacuum. Properly maintained catch basins can help to reduce the quantity of solids that enter the combined sewer system.

LRWWU engages an outside contractor to perform catch basin cleaning throughout the city. It is estimated that about 700 catchbasins are cleaned each year. This practice will be continued but will not be considered further for control of CSOs in the LTCP.

6.6.11 Catch Basin Modifications

Similar to the use of vortex valves, catch basins can be modified with devices, such as hoods or baffles, that help to capture floatables within the catch basin until the sump is cleaned. These devices can effectively remove floatables and coarse solids that may enter the combined system and be discharged to the receiving water. LRWWU installed hoods in its new catch basins installed during the sewer separation program. However, since installing these catch basin modifications will not eliminate or significantly reduce the need for downstream structural CSO controls, this technology will not be considered further for the development of the LTCP.

6.7 Collection System Controls

Collection system controls and modifications are intended to reduce CSO flows within the interceptor system by removing the inflow sources, increasing the use of existing interceptor capacity and pipeline storage, and/or optimizing the performance of the collection system. These controls include sewer line cleaning and flushing, existing system management, sewer separation, infiltration/inflow control, polymer injection (to increase pipe capacity), regulating and backflow gate modifications, real time (remote) system control, and flow diversion.

6.7.1 Existing System Management

System management techniques can improve receiving water quality by reducing CSO discharge volumes and capturing first flush pollutant loads. Regular maintenance of CSO regulators and the interceptor piping system is essential to maintain proper hydraulic conditions in the system and minimize the frequency of CSO discharges. Sediment accumulations or blockages in the regulators or interceptor pipes can reduce the hydraulic capacity of the interceptor connections increasing the frequency of CSO discharges, and in severe cases, causing dry weather overflows.

The city's system management procedures are incorporated into its NMC and CMOM programs. The city regularly inspects the CSO regulator structures and interceptor system and has a comprehensive set of depth monitors in the field to help identify any system obstructions within the interceptor system. The interceptor system has reportedly not required any significant maintenance to eliminate obstructions or to remove sediment. There are also no reported dry weather overflows occurring in Lowell. Finally, based on the results of the model and field sampling programs, the first flush is typically captured and treated at the WWTP. Accordingly, the current program should be adequate to identify problem areas in the system when they arise. No further recommendations are warranted.

6.7.2 Regulator Modifications

Modifications to the operation of regulators can help to reduce CSO discharges by reducing the frequency of activation. Regulators can be modified to pass more flow through to the interceptor or to take advantage of upstream pipeline storage. As discussed in Sections 2, LRWWU has installed a very sophisticated control system to actively modulate most of its CSO diversion stations to optimize the use of the interceptor system to convey flows to the Duck Island WWTF and for pipeline storage to minimize CSO discharges.

Accordingly, no further modifications to the existing CSO regulators are necessary.

6.7.3 Sewer Cleaning/Flushing

Deposition of solids is a common problem in combined sewer systems. These systems are designed to handle peak wet weather flow; therefore their hydraulic capacity greatly exceeds typical dry weather flow rates. Consequently, dry weather flow velocities are usually much lower than the design (full pipe) velocity and may cause solids to settle in the pipelines. During large storms, these solids are resuspended resulting in high pollutant concentrations during the initial period of a storm.

To avoid this “first flush” phenomenon (the resuspension of settled solids due to storm flow) sewers may be cleaned by either mechanical means (rodding or draglines) or by flushing. Either technique will flush the solids through the system during dry weather, when system capacity is available to convey flow to the wastewater treatment plant. This will reduce solids discharged from CSOs to receiving waters during storm events. In severe cases of solids deposition, storm flows will not resuspend the settled materials and the settled solids will eventually accumulate, decreasing the hydraulic capacity of the pipe.

Sewer cleaning is a regular utility program as part of the NMC and CMOM. Past inspections of the interceptor system indicated minimal significant sediment deposition problems. The city performs sewer cleaning, as necessary, to minimize the effects of deposition in problem sewers and within the interceptor system where problems are encountered.

LRWWU TV inspects approximately 5 miles of pipe per year. Prior to TV inspections, the lines are cleaned. More than 30 percent of the piping system has been cleaned by the city over the last 10 years. Accordingly, it is recommended that the city continue with its current practices and cleaning intervals.

6.7.4 Sewer Separation

LRWWU has completed separation of portions of the combined sewer system in several large projects over the last ten years. These projects were required to address localized surcharge and flooding problems. Further recommendations for sewer separation of additional portions of the system will be developed in the review of LTCP options in later sections of the report.

It is important to note that unlike storage and treatment alternatives, which reduce the frequency of CSO discharges, sewer separation eliminates CSOs by diverting all sanitary flow to the wastewater treatment facility. The EPA CSO abatement policies require that combined sewer system separation be evaluated as a step in CSO facilities planning. Although separation eliminates CSOs, it may not, in all cases, be the most appropriate alternative in terms of addressing site specific water quality objectives. By removing the sanitary flow, the CSOs are essentially converted into stormwater outlets, which are now subject to effluent regulations under the NPDES stormwater program. Accordingly, pollutant loadings to receiving waters caused by the sanitary flow in CSOs are eliminated; however,

impacts caused by stormwater borne pollutants may not be. The long-term advantage of any sewer separation must be considered carefully.

6.7.5 Infiltration/Inflow Control

To maximize the collection system's capacity, it is necessary to remove the extraneous flows caused by infiltration and inflow (to the extent possible). Infiltration is groundwater that enters the system through broken or cracked pipes, defective joints, depressed manholes, and manhole walls. Replacing or lining defective pipes and manholes can reduce infiltration.

Inflow results from direct connections to the system from roof leaders, cellar and yard drains, commercial and industrial drains, and malfunctioning tide gates. Since combined sewers are intended to carry both wastewater and stormwater, inflow cannot be entirely eliminated, but can be reduced or retarded to attenuate peak flows. Control of these inflow sources can be addressed by the technologies discussed above.

Under the sewer separation program, LRWWU inspected all of the sewer pipes in the proposed areas of work and completed replacement or rehabilitation of the pipes (to reduce extraneous flow). In addition, LRWWU has an annual program of TV inspections of about 5 miles of sewer each year, which generates additional sewer pipe rehabilitation and replacement requirements that are completed by outside contractors. More than 10,000 feet of pipe have been lined within the last three years, not including all of the lining work completed for the sewer separation projects.

I/I rates during wet weather conditions generally represent only a small portion of the total amount of stormwater runoff activating CSOs, LRWWU. Thus, it is not typically cost effective to address the I/I portion of the drainage basin flow for CSO reduction alone because it is insignificant compared to incremental costs of larger downstream CSO structural controls. Accordingly, while this strategy will not be considered further in the LTCP, LRWWU will continue its existing and aggressive program to reduce I/I.

6.7.6 Polymer Injection

Injecting polymers into a collection system can effectively decrease pipe friction and thereby increase the pipe's hydraulic capacity. A literature search was performed on the use of polymer injection in other combined sewer systems. The EPA performed most of the studies available between 1969 and 1977. According to one source, the addition of a polymer into gravity sewer lines could increase pipe flow to the treatment plant and reduce CSOs. Polymer slurry injections into gravity sewer lines have decreased hydraulic friction and increased pipeline capacities up to 144 percent.

Polymer injection requires the construction of facilities to store and inject the polymer into the pipelines. Instrumentation to monitor flow and regulate polymer dosage is also required. In addition, there are other problems that occur with the use of polymers including polymer coagulation and settling, molecular breakdown of the polymer that reduces its effectiveness, limited storage life, and high cost. Based on these issues, this technology is not considered further.

6.7.7 Regulating Devices and Backwater Gates

This technology utilizes control valves and devices to optimize system operations through the control of flow into and through the interceptor system. Regulating devices include vortex valves, inflatable dams, and motorized or hydraulically operated sluices or control valves, which are used to restrict the conveyance of flow downstream and utilized existing pipeline storage. Backwater gates, such as tide

gates, flap gates, or elastomeric gates, are used to restrict the receiving water from entering the interceptor system.

Several of the CSO outfalls have flap gates and tideflex valves that are continuously inspected by the city and there have been no reported problems with river water entering the interceptor system. In addition, all other CSO diversion gates are controlled locally and remotely by PLCs or WWTF operators. No diversion gate is opened if there is a possibility that the river could flow into the interceptor system. Accordingly, LRWWU has fully implemented this technology and no further consideration in the LTCP is necessary.

6.7.8 Remote Monitoring and Control/Flow Diversion

Diverting flow from one drainage basin having limited hydraulic capacity to a drainage basin having excess capacity can reduce the volume and frequency of CSO discharge. Available and existing pipeline capacity may be used to convey flow or as inline storage. LRWWU has implemented a sophisticated CSO diversion control system using a data gathering system to monitor rainfall, pumping rates, treatment rates and regulator positions; a central computer processing center to provide real time control; and an instrumentation and control system to remotely regulate pumps, gates, valves and regulators.

Further adjustments to this program to address LTCP objectives are not warranted.

6.7.9 Relocation of CSO Outfalls

Relocation of CSO outfalls from sensitive to less sensitive discharge locations is similar to previous sections in that regulator modification and flow diversion may be involved. This solution may also involve routing overflows through a new pipe to a new discharge point, or just raising regulator weirs to force more flow downstream. It also may involve consolidation of CSO discharges to minimize the number of CSO control facilities and aid in their siting.

This strategy does not need to be considered further as most of the CSO discharge directly into the Merrimack River with the same sensitive receptors. The Warren Station outfall discharges into the Concord River but past evaluations have indicated that it is not practical or warranted to relocate this outfall. Similarly, the Beaver Station outfall discharges to Beaver Brook but at the mouth of the brook where it connects to the Merrimack River (with the same receiving water issues).

6.8 Storage Technologies

Storage of CSO flows can be performed either at a local site adjacent to a regulator or other control device or downstream at a central site that consolidates the need for several facilities. Storage facilities are typically used to store CSO discharges for eventual treatment at the WWTP after the storm. However, storage facilities can also be designed to provide some sedimentation treatment capacity for flow greater than the storage volume.

Storage technologies represent more costly structural modifications to a combined sewer system. These modifications are rarely undertaken without a complete assessment of the CSO discharges and interceptor system and the preparation of a system wide facilities plan. These technologies are presented briefly below and include surface storage, inline storage, and off line storage.

6.8.1 Inline Storage

The use of inline storage is considered a cost effective method of reducing combined sewer overflows by utilizing available pipeline storage volume. The storage volume helps to both dampen peak flows and detain combined wastewater for later treatment at the WWTP. Control gates or other devices, such as weirs, can be used to create or optimize inline storage during a rainfall event.

LRWWU utilizes a sophisticated control system to maximize the use of in-line storage within the interceptor system. Past evaluations have indicated that the Read Interceptor could be further utilized for storage and this will be considered in the LTCP. —

6.8.2 Offline Storage

Offline storage and pump back to the interceptor system is one of the most widely used and effective methods for CSO mitigation. Similar to inline storage, off line storage facilities temporarily store wet weather overflow volumes until the flow can eventually be conveyed and treated at the WWTP. Types of storage facilities include underground tanks, abandoned pipelines, or deep tunnels. Off line storage is usually located at overflow points or near dry weather or wet weather treatment facilities. These facilities can be relatively simple in design and operation and can effectively reduce the frequency of overflows.

Storage facilities can also be designed to remove settleable solids, with periodic cleaning by dredging, mechanical chain and flight scrapers, or other means. In effect, some primary treatment (sedimentation) takes place due to quiescent conditions. The settled solids can be handled by:

- Collecting and pumping to the interceptor as a concentrated slurry to be handled at the WWTP during the event.
- Collecting, storing and pumping to the interceptor as a concentrated slurry to be handled at the WWTP after the event
- Collecting and dewatering at the storage site then transported to the sludge processing facilities
- Resuspended in the stored mixed flow during the pump back period for transportation to and handling at the WWTP.

Excessively long detention times can result in the settled solids causing offensive odors. Accordingly, prompt solids removal is necessary along with proper odor control equipment.

6.8.3 Surface Storage

Storing stormwater runoff prior to entering the collection system can be accomplished through roof storage, playground storage, in natural ponds, or in manmade basins or lagoons.

Roof storage can be effective in locations with buildings having flat roofs. However, stored water can seep into the buildings and/or damage the structural integrity of the building. Roof storage is most attractive for new construction in warm climates where snow and ice will not collect on flat roofs. As a demonstration project, LRWWU installed a green roof on top of the Duck Island WWTP Administration Building, which partially stores rainwater. There is also a cistern attached to the surplus roof drainage to provide some additional secondary capture of flow. However, a system-wide program to implement roof storage will not be as effective as downstream CSO controls.

Playground and recreational areas can be used to detain rainfall for a limited time to reduce peak flow in the system. Space availability, public acceptance and potential hazardous conditions are drawbacks associated with method. In addition, use of these facilities to store runoff may interfere with their intended use and increase maintenance requirements. Depending on existing land use and the existing natural topography, temporary stormwater detention may be implemented for runoff attenuation. Storm flow retention in areas having porous soils will allow some or all of the detained flow to infiltrate into the soil instead of entering the combined sewer system.

In general, open space in densely developed urban areas such as Lowell is limited to park and recreational areas and parking lots. LRWWU will consider the application of green infrastructure, like surface storage, as part of its LTCP and an integrated implementation plan.

6.9 Treatment Technologies

Technologies that could be used to treat CSOs prior to discharge, based on the USEPA's guidance manual, are presented and discussed below. Wastewater treatment facility improvements involve improvements at the existing site. The other treatment technologies would be applied at the existing site in a new treatment train or at upstream (satellite) treatment sites.

6.9.1 Wastewater Treatment Plant Improvements

Increasing the capacity of the WWTF to handle higher peak wet weather flows is cost-effective way to reduce the frequency and volume of untreated CSO discharges upstream in the collection system. This approach maintains wet weather treatment facilities at a common site, which could reduce overall operations and maintenance costs.

LRWWU has completed preliminary evaluations of the WWTF dry and wet weather capacities and the capabilities to increase wet weather flow. The limitations to increasing flow are the screw pumps, primary clarifiers, secondary bypass pipe, disinfection contact chamber, and the effluent diffuser (and finished water pumps). It is more realistic to construct an alternative wet weather treatment train, potentially with its own influent pumping station and high rate treatment process. However, this potential solution may also be impractical considering the limited site availability at Duck Island, which may have to be reserved for future WWTF facilities to meeting increasing stringent effluent requirements.

6.9.2 Screening

Screens are effective in removing large solids and floatables from the wastewater flow. The size of the screen openings determines the level of treatment achieved and also the volume of screenings that may be collected. Screens are usually paired with an additional wet weather treatment process such as disinfection or high rate treatment.

Screens for wastewater treatment are available in various types and sizes ranging from bar racks to coarse/fine screens or microstrainers. Microstrainers can achieve primary treatment levels by removing 60 percent of the suspended solids. Screens can be installed at either inline or at off line facilities. Inline facilities must be closely monitored and cleaned to prevent loss of hydraulic capacity, which could cause flooding.

Bar screens are almost always installed at the entrance to storage and treatment facilities for removal of large objects, trash and debris, and to protect treatment and pumping equipment. Often two sets of screens in series are used. The first set usually consists of coarse screens with 1 1/2" bar spacing.

Finer screens with 1/2" to 1" spacing are located just downstream. A double screen set up also has a less tendency to be blocked than one fine screen.

Bar screens may be installed vertically or horizontally. Horizontal screens, like Romag screens, can be used beneficially in some CSO conditions as the screenings could be removed by rakes and deposited back in the flow stream to avoid satellite screen collection issues.

Screening is a viable treatment alternative to help meet CSO control strategies and will be considered in conjunction with another treatment technology to meet water quality/treatment objectives..

6.9.3 Sedimentation

Gravity sedimentation of suspended solids can achieve 20 to 40 percent removal of BOD and 50-70 percent removal of TSS in wet weather flow. It is an additional process that can provide better removal of solids to meet water quality objectives. The major disadvantage of sedimentation is that the land requirements are relatively high. Because the availability of land is usually limited in urban areas, siting of CSO abatement facilities that include sedimentation basins is an important issue.

Sedimentation to be a reliable, cost effective CSO abatement technology and will be considered in developing CSO abatement plans for Lowell. Sedimentation, like screening, will require an additional process to treat CSO discharges to meet water quality objectives.

6.9.4 High-Rate Clarification

High-rate clarification is a newer technology, which can be operated intermittently during storm events. It is a physical-chemical process where coagulant and polymer are added to wastewater to improve settle in small basins. The coagulant aggregates the suspended solids in the flow into a floc. The resulting floc particles adsorb onto either very fine sand added to the wastewater, or recirculated solids with the aid of a polymer. The fine sand (or recirculated solids) acts as ballast and increases the settling rate of the adsorbed floc. Hence, the process is also known as "ballasted flocculation."

A typical ballasted flocculation system consists of addition of ferric chloride, polymer, and "microsand" (sand approximately 100-microns in diameter) to wastewater. The wastewater and additives are rapidly mixed (flash mixing), then slowly stirred in a maturation tank before settling in a clarifier. The sludge from settling is passed through a hydrocyclone, where the microsand is removed from the sludge and recycled. Several suppliers provide enhanced high-rate clarification systems including: Kruger's Actiflo process, which uses microsand as ballast and Degremont Technologies DensaDeg process, which uses recirculated solids as ballast.

Whichever process is selected, BOD and TSS removal rates associated with high-rate clarification have been shown to be roughly double those of traditional clarification (gravity settling) with a smaller basin. Area requirements for the process are about one-tenth of traditional clarification area requirements (5 to 15-percent of the space required for conventional primary treatment). For this same process arc, BOD removal is between 65 and 80-percent and TSS removal is between 70 and 95-percent thus the pollutant removal are closer to secondary treatment standards.

Another form of this process, utilizes secondary solids, as a "bio-ballasted floc" process to improve BOD removal via biological reduction. This approach work when the high rate clarification process is located at a WWTF site.

The high rate clarification process is also beneficial because it can handle high hydraulic loading rates and treat rapidly varying flows (typically observed with “first flushes” and varying precipitation in combined sewer systems).

Storage of chemicals may be of concern at a satellite location, away from the WWTP. Other disadvantages of this technology include the increased operational cost relative to biological treatment and conventional clarification due to the cost of chemicals, ballasted media, and sludge disposal and the limited ability to remove soluble pollutants. Many of the technologies reviewed have limited ability in removing soluble pollutants.

Screening is required prior to the ballasted flocculation treatment component and disinfection is required after. UV disinfection can be utilized with ballasted flocculation treatment because of the high level of suspended solids removal.

In summary, enhanced high-rate clarification provides significantly higher treatment capacities than conventional primary treatment, with significantly higher BOD and TSS removals. Therefore, enhanced high-rate clarification is considered a viable alternative to evaluate further for providing higher wet weather treatment flow capacity and reducing CSOs in the city.

6.9.5 Chemical Flocculation

Chemical flocculation is a high-rate treatment process utilizing metal salts and polymers to aggregate particles in CSO flow. Depending on their density, the aggregate of particles, or floc, will either sink to the bottom or float to the top where it can be removed. A concentrated sludge is produced, requiring no additional thickening. Chemical flocculation can remove 40 to 80-percent BOD and 60 to 90-percent TSS.

Similar to ballasted flocculation, chemical flocculation can handle high hydraulic loading rates and treat rapidly varied flow. Chemical flocculation is limited in its ability to remove soluble pollutants. There is a potential increase in sludge production due to the addition of treatment chemicals and an increased operational cost due to the cost of chemicals. Since ballasted flocculation achieves similar results to chemical flocculation but the hydraulic capacity for chemical flocculation is much less (20,000 gpd/sq. ft for chemical versus 90,000 gpd/sq. ft. for ballasted flocculation); chemical flocculation will not be further considered.

6.9.6 Dissolved Air Flootation

Dissolved air floatation has been used to treat CSOs and has proved to be relatively effective in removing up to 20 to 50 percent of the suspended solids and floatables. Dissolved air floatation (DAF) relies on small air bubbles to suspend particulate matter to float to the surface for removal. Oil, grease, and other floatables can also be removed.

Small and light suspended matter can be removed more efficiently and quickly by this process than by sedimentation. Chemical addition (generally polymer) is usually used to improve removal efficiency. Operating costs are relatively high due to pumping costs to pressurize the water and compressed air, and chemical requirements. The process is also sensitive to operational control.

DAF has been used primarily for processing sludges in municipal, industrial water, and wastewater treatment applications and most recently for water treatment. Due to the relatively high operating costs and sensitivity to operational control associated with DAF, other less costly and complex technologies have been developed that have replaced DAF in many applications.

For the above reasons, DAF is not considered feasible for CSOs and will not be considered further.

6.9.7 Swirl and Helix Concentrators

Swirl regulators/concentrators operate as a solids/liquid separator removing both suspended solids and floatables through rotationally induced forces. Swirls have been reported to remove up to 50 percent of the suspended solids from the combined sewer flow. Helical concentrators are similar in design but are more effective as an inline device (rather than an off line device). The flow is separated into overflow, which is discharged to the receiving water (typically after chlorination) and underflow (a concentrated low volume of wastewater that is intercepted for treatment at a treatment plant).

Swirl and helical bend concentrators have some limitations and potential drawbacks, including:

- The rate of underflow diversion is subject to design limitations relative to the incoming combined flow.
- The relatively short detention time will require high rate disinfection or construction of contact tanks to provide adequate detention time for bacteria kill before discharge to the receiving water.
- The configuration of the swirl concentrator results in a large hydraulic headloss requirement between the influent combined sewer and the underflow pipe.
- Relatively little long-term data on performance and reliability.

Some of the drawbacks can be satisfied by storage and pump back facilities in conjunction with a concentrator, but pumping will also require electricity, additional space, remote/automatic controls for operation and additional costs. Interceptor and treatment capacity must be available for underflow during a storm event. If underflow rates exceed the available interceptor capacity or sufficient grade is not available, the underflow may need to be stored and pump back following the storm may be required.

In order to operate effectively, most swirl concentrators need to be cleaned regularly. A maintenance schedule should be established based on solids loading and accumulation rates. Some types of swirl concentrators must be dewatered and cleaned with a vacuum truck, which will increase work demands of the city's collection system maintenance crews. Other types of systems are designed to pump out the debris that is screened out of the flow, which can potentially create sedimentation and grit accumulation in pipelines.

The uncertainty concerning solids removal efficiencies, the lack of bacteria removal, space requirements and the level of maintenance required for swirls are some of the reason why swirl concentrators are not given further consideration in this study.

6.9.8 Biological Treatment

Biological treatment processes, including contact stabilization, trickling filters, rotating biological contactors, treatment lagoons, and land application, have been most successfully used in the treatment of sanitary sewage and industrial wastewater. Their exclusive use for the treatment of combined sewer overflows has several drawbacks including:

- Difficulty maintaining biomass (used to assimilate nutrients in combined sewage) during dry weather (continuous operation is required);
- Difficulty in handling erratic loading conditions inherent to combined sewer overflows;
- Potential odors and snail population problems;
- High clogging potential;
- Costly operation and maintenance;
- Highly skilled operators are required; and
- Extensive level of treatment provided by biological treatment is not required for combined sewage.

Potentially, CSO discharge into wetlands could provide some level of biological treatment; however, this is not considered appropriate for the city's combined sewer area. Consequently, biological treatment will not be considered further in this study.

6.9.9 Filtration

Filtration is a physical treatment process that removes solids by straining wastewater through a filter medium, such as sand, charcoal (carbon adsorption), or membranes. Deep bed filtration has the ability to treat high and rapidly varying flows. Filtration can consistently achieve secondary treatment concentration standards for BOD and TSS. Its major disadvantage for treatment of combined sewage is the tendency to clog rapidly during use, thus limiting its hydraulic capacity and ability to remove solids; or the need for frequent backwashing to prevent clogging. It can be used after sedimentation to reduce clogging, but this level of treatment is typically not required for CSO applications. Consequently, filtration will not be considered.

6.9.10 Disinfection

Disinfection is used to destroy pathogenic microorganisms. Many disinfection technologies are available including chlorination, ozonation, and ultraviolet radiation. The most common method is chlorine addition, although recently its apparent toxicity to aquatic life is a concern. For this reason, dechlorination is often required.

Disinfection agents used for wastewater and stormwater treatment include gaseous chlorine, hypochlorite (calcium and sodium), chlorine dioxide, and ozone. All of these disinfection agents are oxidizing agents, corrosive to equipment, and are highly toxic to microorganisms and other life. Ultraviolet light has been used as a disinfection agent, but is sometimes ineffective for CSOs because of their turbid mixed flows.

Selecting a CSO disinfection system is based on the following considerations:

- CSOs are highly variable in quantity and quality and thus any disinfection system must have the capability to meet these fluctuations.
- Chlorine, chlorine dioxide, and ozone are all dangerous gases that must be carefully handled by trained operators. Lesser hazards are associated with hypochlorite, which requires bulk storage.

When selecting a disinfection system the capacity and location of the treatment facility must be considered. Use of toxic gases is undesirable in densely populated areas and small scale facilities that are only monitored periodically. For this reason, use of gaseous chlorine is not considered.

Case studies regarding the use of bromine chloride, ozone, and ultraviolet light for CSO disinfection are limited at this time. Ozone has been proven to be effective, although it is considered expensive. Ultraviolet light is typically only effective for flow with lower turbidities. Large particles block much of the light, rendering this technique ineffective.

Generally, chlorination (hypochlorite) is accepted as the most cost-effective and technically reliable disinfection treatment to reduce coliform levels in CSOs. Chlorination will be considered in conjunction with screening, swirl concentrators, and sedimentation. To eliminate the potential toxic effect of residual chlorine on biota, CSOs would be dechlorinated prior to discharge at the wet weather treatment facility under consideration. General dechlorination practice indicates that sodium bisulfite is a reliable and cost-effective chemical to remove chlorine residuals from the wastewater effluent. Chlorination and dechlorination will be considered further in later sections of this report.

6.9.11 Summary of Treatment Technologies

No treatment technology alone is adequate to meet all water quality objectives. However, various combinations of treatment methods may be used to meet CSO abatement goals as discussed in later sections of this report.

6.10 Summary

This assessment has eliminated ten out of thirty-eight technologies from further consideration for the long term CSO facilities in Lowell. These eliminated technologies will not directly address the CSO impacts. Other technologies in this list have already been identified as recommended nine minimum control measures. These technologies will incorporate good maintenance practices to ensure that system operation is maximized to the extent possible before more expensive structural controls are implemented. The remaining controls are more significant in capital requirements and costs. Accordingly, it is more appropriate to discuss these technologies further in later sections of the report, which evaluates the structural CSO mitigation alternatives for Lowell.

Section 7

LRWWU Recommended Implementation Plan

7.1 Introduction

Section 2 identified several projects in need of immediate attention. These include Duck Island WWTF wet weather capacity, a discrete sewer separation project, sewer system surcharge and operational issues, Read Interceptor optimization, and replacement of the West Street Flood Pumping Station (at the Read CSO Station site). LRWWU considers these system improvements to be high priorities that address potential wet weather property damage and public health considerations (basement backups) in the LTCP. These system improvements will ultimately result in CSO reductions.

As alternatives were developed for the incremental control of its CSO discharges, LRWWU identified a number of concerns regarding the development of a prescriptive program to address wet weather discharges for a range of storm events. During the Phase I program, LRWWU successfully implemented an adaptive management approach to the LTCP program that yielded many benefits including cost-effective system controls, which not only reduced CSO discharges but also eliminated system surcharging, utilized existing infrastructure for cost savings, and incrementally built upon previous improvements.

LRWWU believes this phased approach to implementation is superior to the adoption of a long-term prescriptive plan for CSO control. Such a plan would rely on predicted system responses to multiple large-scale improvements, based on numerous assumptions regarding the extents of existing problems and the benefits of future improvements.

Therefore, LRWWU intends to phase the implementation of its CSO control plan for the following reasons:

- The wet weather treatment capacity of the Duck Island WWTF has not yet been fully utilized because of failing equipment and a lack of understanding of peak flow hydraulics. Currently, primary and secondary clarifiers frequently fail during wet weather, limiting treatment capacity. Compounding this limitation, unreliable dewatering equipment (30-year old belt filter presses) often cause high blankets in the secondary clarifiers and further restrict wet weather treatment capacity at Duck Island. These deficiencies must be addressed before consistent wet weather capacity at the plant can be achieved. Moreover, the true peak treatment capacity is unclear, because of new equipment, inaccurate metering, and uncertainty about peak flow hydraulics. Therefore, LRWWU will embark upon a peak flow capacity analysis of the Duck Island WWTF.

- LRWWU is committed to two important improvements at Read Station: the installation of interceptor storage and the construction of a satellite wet-weather treatment facility. The first phase of this crucial project is the implementation of interceptor storage and pumping station at this site; this will be accomplished in CSO Phase 2 LTCP. The pumping station will double as a flood pumping station (to replace the inoperable West Street Flood Pump Station) and an influent pumping station for a future 60 mgd wet-weather treatment facility. The treatment facility will be constructed in C SO Phase 3 LTCP. Once completed, the Read facility will

substantially increase system-wide wet weather treatment capacity (approximately 60%) and provide significant control of the North Bank Interceptor (including Walker, Beaver Brook, West, and Read stations). LRWWU believes that it would be premature to make definitive plans beyond the Read improvements until the benefits of this work are fully understood.

- LRWWU has concerns with the predictive capacity of the SWMM model for larger storm events. Generally, the utility does not favor the use of a model, calibrated with a short-term set of flow monitoring data, to develop strategies for the long term control of sewer surcharging and CSO discharges. LRWWU's plan relies on evaluation of benefits based on actual impacts, rather than predicted outcomes. Accordingly, LRWWU is committed to conducting level monitoring, model calibration, and further analysis during the implementation of the Phase 2 and Phase 3 programs over the next eleven years to confirm project benefits with actual system responses to peak flows.
- Potential regulatory changes to the Duck Island WWTF NPDES permit may necessitate future process changes that require expansion of the treatment facility. The WWTF site has minimal available land for new tankage; if future regulations require a dry weather process change, then this land may not be available for CSO treatment or storage facilities. This circumstance significantly impacts the development of a long-term (greater than ten years) CSO strategy.
- LRWWU intends to incorporate green infrastructure into its plan for CSO control. The utility has constructed green infrastructure at the Duck Island facility to demonstrate the effectiveness of porous pavement, green roofs, cisterns, rain gardens, and stormwater retention ponds in managing stormwater. In addition, LRWWU has worked with the Lowell Green Building Commission to advance the opportunities to incorporate green infrastructure in the city. LRWWU is committed to advancing the benefits of green infrastructure and intends to fund a green infrastructure project in South Common, one of the city's major parks, to demonstrate infiltration strategies, educate the public about stormwater management, and inspire private developers to install green infrastructure. At this time, it is unclear exactly what role green solutions will play in the ultimate plan for CSO control, particularly on the South Bank of the Merrimack River, where impervious cover is extensive and gray infrastructure options are limited.

7.2 Overview of the LRWWU Plan

Based on the successful implementation of CSO Phase I LTCP improvements, LRWWU has guided the development of alternatives based on a phased implementation plan for the LTCP. During the development of LRWWU's Phase 2 and Phase 3 plan, the focus was directed on the range of improvements required to match available funding and competing needs. LRWWU established a budget of about \$120 million in capital spending and annual program expenditures over ten years, which reflects the past Phase I LRWWU spending rate.

LRWWU's approach for Phase 2 and Phase 3 is to focus on improvements that maximize wet-weather treatment and storage capabilities, resolve long-standing sewer surcharge problems, sustain critical transport and treatment infrastructure, maintain permit compliance, and reduce CSOs from Lowell's combined sewer system. Accordingly, LRWWU is submitting an integrated plan, discussed herein, with components that address needs in the following compliance areas: MS4, CMOM, CIP, and CSO.

The general program features that LRWWU intends to implement in Phase 2 and the Phase 3 are:

- Sewer Rehabilitation (CMOM)
- Stormwater Management (MS4)
- LTCP-CIP Planning (Monitoring, Assessment, and Prioritization)
- Combined Sewer System Improvements (Separation, Capacity, and Conveyance)
- WWTF Peak Treatment & Pump Station Upgrades (Duck Island and satellite stations)
- Flood Pumping and Interceptor Storage (Read Station)
- Wet Weather Treatment Facility (Read Station)
- Wet Weather Storage Facilities (Walker, Douglas, Pevey, and Middlesex)

The projects contained within each program are discussed below. Phase 2 represents approximately \$52 million in spending over a five year implementation period. Phase 3 represents expenditures of about \$71 million over a five year implementation period. Altogether, the LRWWU plan commits to \$123 million during the next eleven years.

Table 7-1 and Table 7-2 summarize the Phase 2 and Phase 3 LTCP/CIP programs, respectively. The Phase 2 summary shows the scope, schedule, and budget for the targeted projects, while Phase 3 project details are mostly to-be-determined (TBD). In between the two phases, LRWWU is proposing a one-year assessment period in order to identify the benefits of the Phase 2 program and finalize the subsequent improvements for CSO Phase 3 LTCP.

7.3 LTCP Planning

As part of the phased approach, LRWWU intends to undertake a continuous assessment of the projects in Phase 2 and Phase 3 of the LTCP Plan implementation to help inform the next phase of work. An important aspect of this assessment is continuous monitoring of the system to continually improve model accuracy during a range of storm events and to assess the efficacy of the improvements as are they are implemented. LRWWU would like to capture data on system responses to larger, intense, storm events that often create problems in the system.

Accordingly, LRWWU has budgeted about \$1 million for the LTCP Phase 3 Plan and LTCP Phase 4, which will entail additional system monitoring at key locations most likely utilizing depth recording devices to identify system surcharge impacts during large storm events. In addition, LRWWU will continue to rely on its extensive set of depth and flow meters already installed at most of the CSO stations. The work will also entail further calibration and verification of the SWMM model to match field conditions. LRWWU believes a more robust model is required to complete the planning for later phases of the LTCP, which may require significant expenditures for satellite storage or treatment facilities.

As a second part of the LTCP Planning, LRWWU intends to conduct a continuous assessment of the program implementation. In the discussions below, LRWWU acknowledges that adequate funding may not be available to completely eliminate system surcharges in the Marginal-Pevy-Middlesex corridor during the Phase 2 program. If necessary, this project will be completed in Phase 3. Should this occur, LRWWU will modify project scopes so that a balanced approach may be undertaken to meet the utility's system performance objectives. LRWWU has budgeted \$1 million in each program to evaluate capital planning objectives.

7.4 Sewer Rehabilitation and Stormwater Management

As discussed in Section 3, LRWWU continues to self-perform an extensive annual program of cleaning and television inspections and assessment of the sewer collection piping system, and a stormwater management program to address permitting requirements of the MS4 General NPDES Stormwater Permit. Based on the assessment of pipe conditions, LRWWU selects to either replace or rehabilitate (CIPP lining) the existing pipes. Pipe replacement and rehabilitation is performed by outside contractors based on two individual programs: emergency and noon-emergency sewer repairs. LRWWU will continue this program of assessment and piping system rehabilitation with a total budget of \$8 million in Phase 2 and \$10 million in Phase 3.

For stormwater, LRWWU will continue to inspect outfalls, map its drainage system, and administer its illicit discharge detection program. In addition, LRWWU will continue to update its GIS mapping of the stormwater system based on field inspections. LRWWU is budgeting approximately \$1 million in each phase in its operating budget to conduct these stormwater management tasks.

7.5 Combined Sewer System Improvements

LRWWU has identified four projects that will be part of the Sewer System Improvements portion of the Phase 2 LTCP Plan. These projects incorporate partial sewer separation in a portion of the Tilden CSO basin, installation of green infrastructure in the Warren CSO basin, and resolution of sewer surcharging along the Marginal/Middlesex Interceptor.

7.5.1 University Crossing Sewer Separation

In Phase 1, LRWWU completed sewer separation of the Cabot Street area in the Tilden CSO basin and implemented automatic gate control to optimize the use of the Tilden Interceptor for wet-weather storage. This effort has significantly reduced CSOs but the activation frequency is still high. A range of alternatives were considered for the Tilden drainage area to reduce CSO discharges further. Since there is a lack of available land for satellite treatment and storage facilities in this basin, sewer separation of the upstream combined system, and the utilization of green infrastructure throughout the basin, will likely be the best strategy for eventual control of the Tilden CSO Station. LRWWU also has concerns about the vulnerability of the Lower Tilden Interceptor, downstream of the Tilden Station, because of restricted accessibility. As the LTCP evolves, LRWWU believes that another conveyance option for the Tilden flows may be required in the future, potentially requiring new siphons to convey this flow over to the North Bank interceptor system. In the meantime, LRWWU is moving forward with projects that involve separation and infiltration in portions of the Tilden basin.

The remaining combined area is comprised of commercial and residential properties in the Acre neighborhood and downtown portion of the city surrounded by the Lowell locks and canals system. Hydraulic modeling suggests that nearly 60 percent (158 acres) of the remaining combined area would need to be separated in order to achieve the 3-month level of control. New drainage outlets

would most likely need to discharge to the canal system, which will require easements and approval from the canal owners. In addition, the separation projects will be more complex and costly since they are in a heavily trafficked and commercialized area. Accordingly, the implementation of green infrastructure to retain stormwater flow may be an attractive option in this basin.

For the Phase 2 program, LRWWU has identified a 10 acre portion of this combined area to separate. This project will take advantage of an existing drain line, which conveys flow to a drainage outfall into the Merrimack River (installed in the recent Cabot Street sewer separation project, as shown in Figure 7-1). The project also represents another public-private partnership to separate combined sewer areas. In this project, UMass Lowell's new University Crossing development would be fully separated from the sewer system, a project that UMass Lowell is indirectly paying for under a temporary stormwater discharge fee agreement. LRWWU is budgeting approximately \$2.5 million for this project, including 20 percent for engineering and contingencies. Separation of this area may yield a CSO reduction of about 4 MG per year on average.

LRWWU will continue to investigate alternatives to complete more separation of this area as the area develops further. In addition, more CSO reduction benefit may be achieved by adding green infrastructure in this area. Hydraulic modeling indicates that if 50 percent of the remaining combined area employed green infrastructure, a 3-month level of control might be achieved. A green infrastructure strategy will be considered further as LRWWU completes and evaluates the efficacy of the proposed stormwater infiltration project in CSO Phase 2 LTCP.

7.5.2 Marginal Street Sewer Relief Pipe

7.5.2.1 Background - Marginal/Middlesex Interceptor Surge Relief Improvements

As described in Section 2, the Marginal/Middlesex Interceptor conveys large amounts of flow from the upstream Warren CSO Basin along the Pawtucket Canal to the Warren CSO Station. In 1988, Lowell was required by a consent decree to close the Pevey Street and Thorndike Street CSO regulator/outfalls into the Pawtucket Canal. Capping these outfalls created sewer system surcharging during intense storm events, a condition that persists to this day.

LRWWU has identified incidences of street flooding and basement backups at three key points along this interceptor:

- a low point along Marginal Street near the UMass Lowell South Campus;
- from a manhole on private property near the former Pevey CSO regulator structure; and
- near the Boys and Girls Club along the Middlesex Interceptor (street flooding and basement backups), which is at a low point upstream of the former Thorndike Street CSO regulator.

It is clear that surcharging relief must be employed at these locations. However, LRWWU lacks a good understanding of the conditions in this sewer line. Therefore, a stepwise approach is recommended, with two projects proposed for the Phase 2 program and another for the Phase 3 program. The benefits of the Marginal Relief Pipe and the Middlesex Relief Pipe projects will be evaluated before finalizing the scope of the Pevey Relief/Storage project.

Hydraulic modeling of the problems along this interceptor was performed to evaluate alternatives. Based on model simulations, sewer surcharge becomes severe during a 2 year or larger storm event frequency. Accordingly, alternatives were considered to eliminate the system surcharges using the SWMM model, as discussed below. These alternatives were developed to consider a phased implementation. As noted, LRWWU intends to update the model for larger storm events before fully adopting a comprehensive solution to the problems along this interceptor. In addition, a preliminary design must be completed to address constructability issues with each alternative before a comprehensive solution can be adopted.

Alternatives considered to resolve the sewer surcharge in this area included sewer separation, larger conveyance or relief interceptors, offline storage facilities, and a relief pipe or a pump station to redirect flow out of the Warren CSO Basin (to the nearby Walker Interceptor and CSO station). LRWWU's goal was to eliminate these for the 2 year storm event, based on SWMM simulations, but additional control may be required in the future.

Solutions to the three surcharge locations along the interceptor system were considered discretely and as a system-wide solution, as discussed below. LRWWU will implement solutions to the Marginal Street surcharge and the surcharge at the Boys & Girls Club in the Sewer System Improvements program and solutions to the surcharge near the old Pevey CSO in the Sewer Rehabilitation, Stormwater Management, Wet Weather Storage and Flood Pumping program.

7.5.2.2 Partial Sewer Separation Alternatives

Partial sewer separation of portions of the area was considered to reduce the excess flow along the Marginal and Middlesex Interceptors. This partial sewer separation area was considered because there is existing drainage piping in the area that discharges to the Lowell canal system. LRWWU expected that this area could be readily separated and discharged into the canal via new outfalls.

Based on hydraulic modeling using the current SWMM model, approximately 230 acres of the combined sewer area upstream of the closed Pevey and Thornlike outfalls could be separated to significantly reduce surcharging and surface flooding along Marginal and Middlesex Interceptors to achieve LRWWU's goals for the 2 year storm event. Topography in the area suggested that another 130 acres adjacent to the canal could also be readily separated, but this additional separation acreage may not achieve sufficient reduction of surcharge issues for the 5 year event, according to current model simulations.

The approximate construction cost of separating the 230 acres is about \$23 million. As this alternative would require significant time to implement, and would require significant disruption of the area, LRWWU investigated other alternatives.

7.5.2.3 Storage Opportunities and Marginal Interceptor conflicts

There are large areas of city owned land near the closed Pevey and Thornlike outfalls where a storage facility could be potentially be constructed. Three sites in particular were identified during the site investigations - Site 1 (Walker CSO Station), Site 2 (Along Pawtucket Canal) and Site 14 (Clemente Park, abutting Boys and Girls Club). These sites are described in detail in Appendix D.

Both the Pawtucket site and the Walker CSO Station would require large diameter conveyance piping to connect the interceptor relief points to the proposed storage facilities. This conveyance pipe would have to be routed under an active MBTA railroad and cross country along the Pawtucket canal. The

facility in Clemente Park would be easier to incorporate since the Marginal interceptor runs directly through the site.

Upstream Marginal Interceptor surcharge problems may not be addressed by these downstream storage solutions because of the limited conveyance capacity of the interceptor. Accordingly, the size of the Marginal Interceptor would have to be increased. LRWWU considered the alternative to increase the size of the Marginal Interceptor to be impractical (to utilize downstream storage solutions at the other two locations) because of the lack of available land for construction along the existing pipe. Therefore, separate solutions for the Marginal Interceptor were considered.

7.5.2.4 Marginal Interceptor Relief Pipe

A relief pipe constructed at the Marginal Street surcharge location to redirect flow to the Walker Interceptor (utilizing a route over partially city-owned land) near the DPW garage could potentially reduce the Marginal Street surcharge to acceptable levels to minimize the risk to existing properties along Marginal Street. This solution also provided some limited downstream relief to the Pevy and Boys and Girls club site surcharge locations during a 2-year storm event.

One consequence of this proposed relief pipe is that this additional flow could overwhelm the Walker Interceptor, creating inadvertent and adverse Walker Interceptor surcharge. Diverting too much flow to the Walker Interceptor above the 2 year storm may require additional improvements including a parallel interceptor (to the existing Walker Interceptor) and/or downstream storage facilities (at Walker Station) to minimize downstream surcharge HGL conditions. A full diversion of the flow from the Marginal Interceptor would just cause problems elsewhere. Accordingly, any new Marginal Interceptor relief pipe had to be conceptually sized to balance the competing need to reduce surcharge along the Marginal Interceptor without causing flooding along the Walker Interceptor. Initial hydraulic modeling suggested some appropriate relief pipe sizes for the 2 year and 5 year storm events but additional flow monitoring will be required to validate the required pipe sizes to balance these competing needs.

A 24-inch diameter relief pipe from the interceptor on Marginal Street, between the DPW property and the UMass Riverview Dormitories, connected to the Walker Interceptor could reduce surcharging and minimize the risk of sewer backups up to the 2 year storm. A larger conduit would adversely impact the Walker Interceptor and the low, downstream area near Walker Station, unless a Walker Interceptor relief pipe and potentially downstream storage were constructed. The alignment of the Marginal Street Relief pipe requires crossing an active MBTA railroad as shown in Figure 7-2.

As indicated above, LRWWU intends to complete flow monitoring in the area to validate the model for a 2 year and greater storm event to help adequately size the Marginal Interceptor Relief pipe and preserve other alternative surcharge relief strategies that LRWWU may undertake later. Accordingly, LRWWU proposes to install a larger diameter pipe (at least a 36 inch diameter) as part of its phased program, in the event that the Walker Interceptor is modified to increase conveyance capacity. A flow control device will be installed to modulate the pipe capacity to the equivalent flow of the 24-inch pipe so as not to overwhelm the downstream Walker Interceptor. These types of devices are manufactured as a single unit which controls the opening of an orifice based on the hydraulic head at the upstream structure and restricts the flow to a maximum flow rate. These units can also be adjusted in the future if too much or too little flow is being conveyed. This project allows LRWWU to monitor and adjust the surcharge levels to minimize the risk to the adjacent properties.



Legend

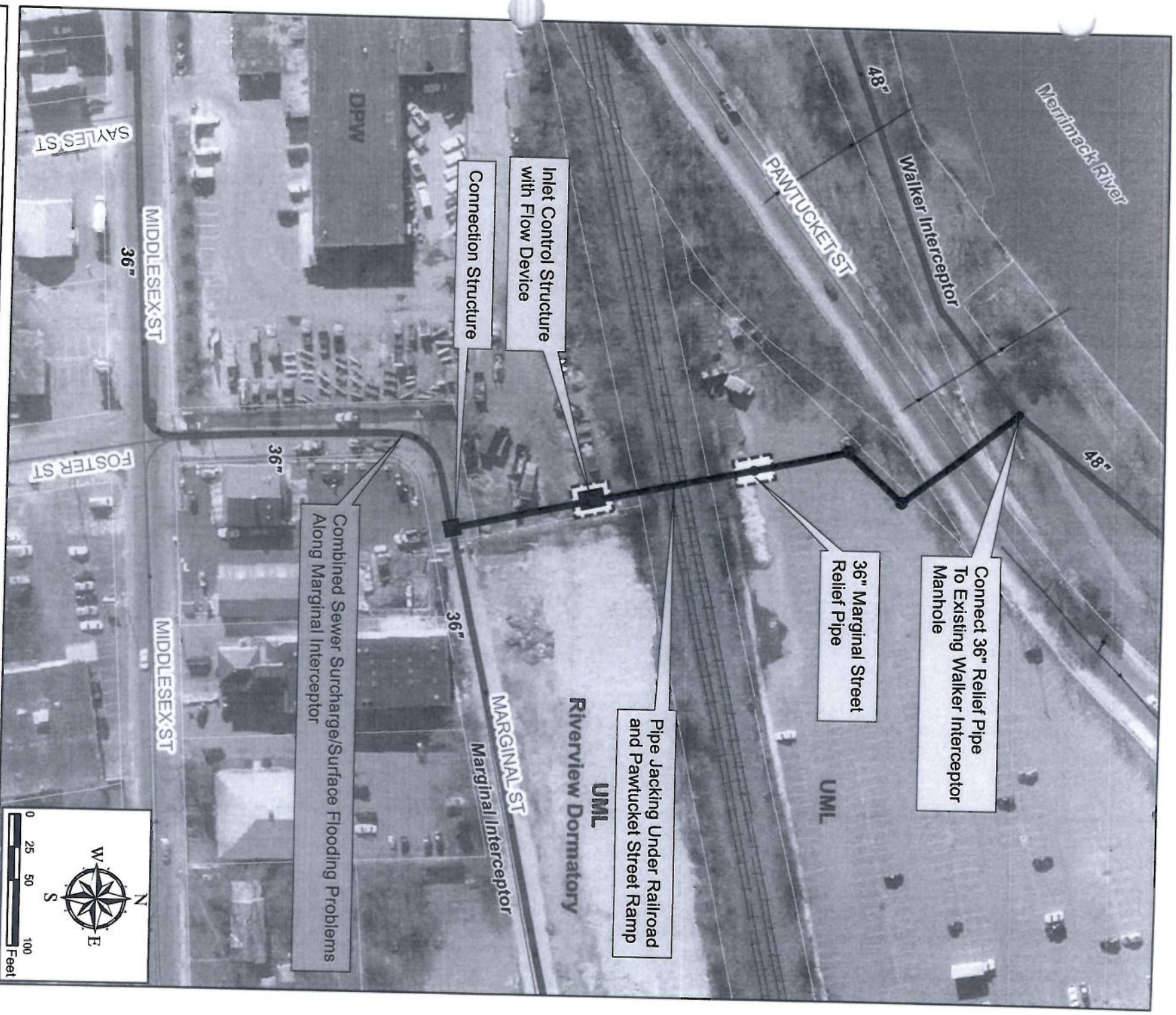
Existing Drain
Existing Sewer

Existing Interceptor
Marginal Relief Pipe

Jacking Pit
Parcels

Lowell, Massachusetts
CSO Phase 2 LTCP

Figure 7-2
Marginal Street Relief Pipe



LRWWU is budgeting approximately \$3 million for the installation of the Marginal Interceptor Relief pipe including 20 percent for engineering and contingencies. This does not include any costs for site acquisition, railroad crossing challenges, unsuitable soils or rock, and other unanticipated conditions. Accordingly, LRWWU intends to complete preliminary design to further assess the constructability and costs for the option.

7.5.3 Middlesex Interceptor Surcharge Relief

When the old Pevey and Thornldike CSO outfalls were removed from the system, interceptor relief was removed where it was needed the most. LRWWU has periodically received reports of surface flooding near the Boy and Girls Club where the interceptor runs under the building and where there is a low point along the interceptor. The Boys and Girls Club is located just upstream of a large diameter sewer collector pipe connection to the Middlesex Interceptor and upstream from the old Thornldike CSO regulator. Hydraulic modeling indicated that there is significant surcharging near the Boys & Girls Club for storms greater than 2 years; however, existing reporting data from LRWWU is not adequate to confirm this frequency. Thus, further system monitoring is necessary.

The SWMM model also suggested that there could be surcharge along the Middlesex Interceptor near the old Pevey CSO regulator at about the 2 year frequency. LRWWU has received reports of surcharging in the area but further investigation is needed to better understand the local system response to wet weather. Again, because of the lack of formal surcharge reporting data and a deficiency in sewer level information in this area, LRWWU intends to perform further field monitoring along the interceptor to help characterize the interceptor surcharge better.

However, for the purposes of formulating the Phase 2 program, LRWWU investigated several alternatives to help alleviate the sewer surcharge problems in both of these locations. The solutions to the Boys & Girls club surcharge problems are discussed below. The surcharge relief solutions for the Pevey Street area are discussed in another program later in this section.

7.5.4 Boys and Girls Club

To reduce system surcharge along the reach of interceptor near the Boys and Girls Club, local system improvements could be implemented. Local system improvements considered in this analysis included the construction of a sewer service grinder pumping station to pump the sewer flow from the Boys and Girls Club into the interceptor to avoid any backflow from the interceptor during surcharge conditions. Another local improvement that could be implemented is the relocation of a portion of the Middlesex Interceptor from underneath the building and the low topographic area. By relocating the pipe to the local street instead of the cross country area, the surcharge should stay in the pipe instead of being relieved from the low manhole on the Boys and Girls property, which should decrease the probability of damages.

LRWWU recognizes that these solutions may only create problems in other areas and a more comprehensive solution may be required for this segment of the interceptor. Local storage in Clemente Park, just upstream of the Boys and Girls Club and adjacent to the Middlesex Interceptor, could help relieve the surcharge along the pipe. However, the storage facility may be exceptionally large – 2 or 3 million gallons – depending on further flow monitoring in the area and the design storm control level that is selected. Hydraulic analysis also showed that a storage facility located at Clemente Park will reduce the surcharge at the Pevey location along the Middlesex Interceptor (because there is not adequate capacity at Pevey to convey this excess flow downstream. Thus, a more comprehensive

solution may be required for a joint long-term reduction of both the Pevey and Boys and Girls Club locations.

LRWWU recognizes that the solution to the Middlesex Interceptor surcharge problems must be a phased approach to balance short term benefits and long-term costs. It is a good practice to relocate the interceptor out from underneath the building. So this may be the first phase that LRWWU will implement to help address the Boys and Girls Club problem. However, LRWWU is also suggesting that incremental storage near the Boys & Girls club, either via the rerouted pipeline, or in Clemente Park, may also provide benefits. The next phase to fully address the problems at the club will likely be integrated with a surcharge solution for the Pevey portion of the Middlesex Interceptor.

LRWWU has budgeted approximately \$3 million to complete a system improvement in this location to help relief surcharge at the Boys & Girls club, potentially comprising the relocation of the Middlesex Interceptor or wet-weather storage facility. This cost includes approximately 20 percent for engineering and contingencies.

7.5.5 Pevey Street Relief/Storage

As discussed in Section 7.5.2.1, there are three locations along the Marginal/Middlesex Interceptor that experienced surcharge conditions during wet weather events. The Marginal Street area and Boys & Girls club surcharge issues will be addressed in the Sewer System Improvements program as part of the Phase 2 LTCP (as discussed above). The last surcharge area along this interceptor system is at the old Pevey CSO regulator.

There are several options that could be implemented to relieve surcharge at this location. Replacement of the existing interceptor down to the Warren station, to convey all of the excess flow downstream, was evaluated; this option is considered impractical due to the existing pipe route along very congested and narrow streets along the canal and the exorbitant costs. There is no available parallel route that could be used for a relief pipe.

Several other options were also considered as shown in Figure 7-3:

- Construction of a new relief pipe from the old Pevey outfall that would be connected to the Walker Interceptor (similar to the Marginal Street relief pipe approach). The pipe would be approximately 3,000 feet in length and at least a 54-inch pipe in diameter (to convey flow by gravity). The pipe route requires crossing under active MBTA railroad and would also require either construction through a state park or very deep construction (greater than 25 feet deep) along city streets. In addition, a 0.6 MG storage facility may be required at the Walker CSO Station, based on hydraulic modeling, to prevent the excess flow from the Middlesex Interceptor from overwhelming the Walker Interceptor. Conveying this surcharge flow to the Walker CSO Station may slightly increase CSOs downstream.

- Construction of a peak flow pump station at a city-owned property at 91 Pevey Street to convey flow to the Walker Interceptor. The benefit of a peak flow pumping station is that the force main might be a smaller pipe and it could be installed shallower than a gravity pipe. If a pumping station were constructed, the approach would be to pump a portion of the peak excess flow rate (estimated at about 50 mgd using the hydraulic model) and provide wet well storage to dampen the peak. It was approximated that a 10 mgd pump station could be constructed on the site with a wet well volume sized suitably to capture peak flow rate greater than 10 mgd.

- Construction of a wet-weather storage facility at 91 Pevey Street. This alternative may be impractical if initial model simulations are accurate (approximately 2 MG may be required to store the excess surcharge flow along the Middlesex Interceptor). However, this solution may become more viable if future monitoring and other system improvements result in a reduced storage capacity.
- Construction of a parallel relief pipe to Clemente Park where a storage facility could be constructed and combined as part of the permanent solution for the Boys & Girls Club surcharge problems.

As discussed above, hydraulic modeling of the Marginal/Middlesex surcharge problems indicates that adverse surcharging is created during storm events equal to or greater than the 2 year event. Anecdotal information about reported surcharging conflicts with this prediction and LRWWU intends to complete comprehensive depth monitoring along the interceptor to fully characterize the local sewer system and inform LRWWU about the best alternative. Monitoring of large storm events will be invaluable in determining practical and cost-effective solutions to these surcharge problems.

The estimated project costs for fully implementation of these alternative solutions ranges from \$10 million to \$16 million including 20 percent for engineering and contingencies. This does not include any costs for site acquisition, railroad crossing challenges, unsuitable soils or rock, and other unanticipated conditions. To initiate this work, LRWWU has budgeted about \$4 million. Remaining funding for full implementation of the solution will be obtained from the Phase 3 LTCP program.

7.5.6 Stormwater Infiltration

LRWWU intends to develop an integrated plan that relies on green infrastructure and stormwater infiltration to achieve its CSO reduction and stormwater control goals. As discussed previously, LRWWU has already installed green infrastructure as demonstration projects at the Duck Island facility. In the Phase 2 program, LRWWU is proposing to implement an infiltration project in the combined sewer system to increase public awareness of the benefits of green infrastructure.

While LRWWU will need to investigate where this project may ultimately be implemented, one potential project involves South Common Park and the adjacent Rogers School. South Common is a 20 acre park that accommodates a number of public facilities including tennis courts, public pool, walking paths, a large flat roof building, and several paved roads and parking areas. South Common is located within a combined sewer area that contributes to Warren. LRWWU has identified this public space as an ideal location to showcase stormwater infiltration and green infrastructure. See Figure 7-4.

In Phase 2, the impervious area would be reduced by removing the runoff from the flat roof of the school building and paved areas from the sewer system and connecting it to an infiltration gallery or rain gardens. Paved areas could be replaced with porous pavements. As mentioned in Section 3, LRWWU has already gained experience with this type of projects at the WWTf and would apply their knowledge to a larger scale public showcase. Kiosks would be installed in the park to educate the public about the project and its benefits. LRWWU has budgeted approximately \$0.5 million for this project, including 20 percent for engineering and contingencies.

LRWWU has also identified other potential locations for infiltration projects that may provide similar benefits and have the same public exposure. These sites will be evaluated as potential projects in future phases of LRWWU's LTCP plan.



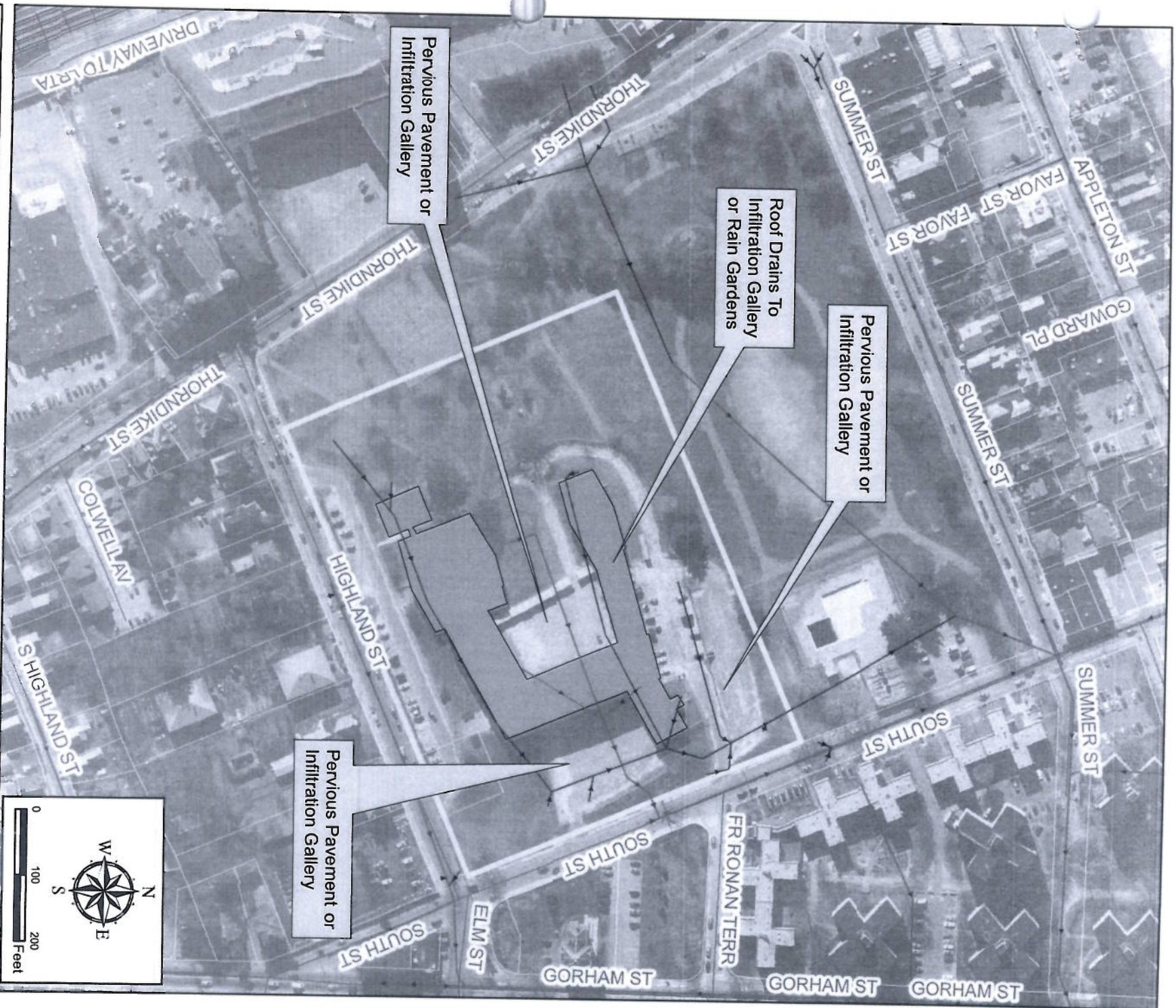
Legend

- Existing Drain
- Existing Sewer
- South Common Site
- Public Building

South Common Stormwater Infiltration
and Green Infrastructure

Lowell, Massachusetts
CSO Phase 2 LTCP

Figure 7-4



7.6 WWTF Capacity and Pump Station Improvements

Wet weather treatment capacity at the Duck Island WWTF is often limited by existing process equipment that is off-line for repairs, including the failing primary and secondary clarifiers and the solids dewatering system (belt filter presses). These repairs are included in the WWTF CIP discussed in Section 3. LRWWU intends to complete these plant improvements, along with upgrades to its remote stations, which will increase operational efficiencies and wet weather capacity.

7.6.1 WWTF Peak Flow Treatment

LRWWU has identified a set of projects at the Duck Island WWTF that will increase the reliable wet weather treatment capacity at the plant. LRWWU has completed a very comprehensive set of improvements to the Duck Island WWTF as part of its CIP. These improvements were focused on odor control, process improvements, replacement of aging equipment, and increasing wet weather treatment capacity. However, Duck Island WWTF operations are still frequently challenged by breakdowns of several remaining pieces of equipment that must be replaced to ensure the maximum level of treatment capacity during wet weather storm events. The improvements include permanent replacement of the failing belt filter presses with new centrifuges that will maintain an adequate solids dewatering train, providing capacity for the solids generated by treating higher flows during wet weather. In addition, LRWWU must rehabilitate its primary and secondary clarifiers (inner mechanisms and solids pumping). The frequency of clarifier breakdowns due to aging equipment is increasing, which significantly affects overall hydraulic capacity during wet weather events.

Concurrent with these improvements, LRWWU intends to conduct an analysis to determine the hydraulic and process capacity at the WWTF to convey and treat wet weather flows. Based on this assessment, LRWWU will verify the reliable high flow that can be processed at Duck Island, which will inform the development of the LTCP as it progresses to further CSO reduction goals.

LRWWU will expend about \$8 million to complete these improvements.

7.6.2 WWTF Improvements and Remote Station Upgrades

In addition to the peak flow improvements program, there are other electrical and structural improvements that need to be completed in association with the clarifier and centrifuge projects, including upgrades to the solids handling system, and miscellaneous process and electrical system upgrades. This work is included in the CIP program and is being prioritized to help maximize the wet weather treatment capacity at the WWTF.

LRWWU also intends to complete facility upgrades at remote CSO diversion and sewer pump stations to integrate the flow monitoring, operations monitoring, and pump and gate control at each of these stations into LRWWU's comprehensive SCADA control system. In addition, LRWWU intends to update various mechanical and electrical systems at some of the older pump stations to accomplish this control integration.

The estimated project cost for these improvements is \$3 million, including 20 percent for engineering and contingencies.

7.7 Flood Pumping and Wet Weather Storage

LRWWU has identified two important projects that utilize the Read Interceptor for wet weather storage and construct wet-weather treatment facilities at the same site as a flood pumping station.

7.7.1 Read Pump Station and Interceptor Storage

As discussed in Section 2, the West Street Flood Pumping Station is inoperable and the pump capacity necessary to evacuate interior drainage flow from the combined sewer system during river flood conditions must be replaced to meet FEMA requirements. During the Phase I LTCP program, LRWWU completed discrete system investigations that identified opportunities to consolidate interceptor system optimization, flood pumping, and a CSO treatment system within city-owned property adjacent to the Read CSO Station as an integrated approach.

7.7.1.1 Read Interceptor Storage

LRWWU currently utilizes a sophisticated real-time control system to optimize the use of the interceptor piping network to storage wet weather flow and minimize CSO discharges during storm events. Each significant reach of the interceptor system is optimized using the existing CSO control stations that store wet-weather flow in the upstream interceptor reach. As discussed in Section 3, during the development of the High Flow Management Plan, LRWWU noted that there was one remaining segment of the interceptor system, along the North Bank of the Merrimack River, upstream of the Read CSO station, which could be utilized for additional wet weather storage.

The Read CSO Station regulates combined sewer flow from a discrete upstream drainage basin east of Bridge Street and does not regulate flow along the North Bank Interceptor. Accordingly, LRWWU recognized that a new control structure would have to be constructed to optimize the use of the 96-inch Read Interceptor for wet weather storage. LRWWU has estimated that about 0.75 MG could be stored in the Read Interceptor if the control structure were constructed. During this assessment, LRWWU recognized that a new flood pumping station (to replace the West Street Flood Pumping Station) could be integrated with the new Read Interceptor Control Structure at the Read site.

The proposed Read Interceptor optimization control structure would be installed upstream of the drop along the interceptor system where it transitions to the Duck Island Interceptor. The control structure would be equipped with an inline control gate that would actuate with water levels to store wet weather flow within the Read Interceptor. Another control gate would be installed to be able to direct excess flow into the Read Pump Station.

The structure could not be located along the existing interceptor because it is within the flood plain. Accordingly, new interceptor pipes would convey the flow beyond the river bank from Interceptor Control Structure 1 (as shown on Figure 7-5) to Interceptor Control Structure 2, which would contain the control gates. During dry weather conditions flows would be redirected back to the last segment of the Read Interceptor to be conveyed to the WWTf for treatment. During wet weather conditions flows could be stored within the Read Interceptor or directed towards the pump station if needed for flood pumping or future CSO treatment.

This structure was designed and bid in August 2011. However, due to funding limitations and the ongoing consideration of the construction required for the related flood pump station design, the project was postponed.

7.7.1.2 Read Pump Station

As described in Section 2, the West CSO Station was originally constructed as a flood pumping station as part of the Centralville Flood Protection Project by USACE in the late 1930s. During high river conditions, the station used to evacuate all of the combined sewer flow collected in the Centralville neighborhood and discharge into the Merrimack River. In the late 1970s, the north bank interceptor system was constructed and collected the flows from Centralville and conveyed them down to the Duck Island WWTF. This interceptor conveyance capacity reduced the need to pump flow into the river during storm events.

Today the flood control pump station is inoperable and, according to the USACE, adequate pump capacity must be installed to ensure that the interior drainage area in the Centralville neighborhood can be conveyed into the river during flood conditions (to return the flood protection system back into active status according to USACE regulations). As discussed in Section 2, for various reasons, rehabilitation of the existing station was not feasible. Accordingly, LRWU completed detailed analyses to evaluate the potential to utilize the Read Interceptor to convey flow downstream to the Read CSO station site, where there was land available to construct a new flood pump station.

In addition, an analysis was performed to determine the size of the pumping capacity required to meet interior flood protection requirements with coincidental storm conditions and high river elevations. The original pump station was constructed to pump about 175 MGD into the river during a coincidental rain storm and high river condition. However, since the original 1930s design, the Merrimack River has become more controlled with upstream impoundments. Further study has also shown that the river has a lengthy time of concentration. Thus, the larger storm events would cause the flood condition but not occur concurrently with the flood condition. Accordingly, it is less likely to have a similar extreme event like the 1930s floods, which caused catastrophic damage in the city. A series of probabilistic evaluations were conducted to determine the coincidental rain storm and high river elevation using the existing interceptor system and a potential new flood pump station at the Read Street. The goal was to achieve a 100-year frequency flood control target for flood protection behind the levee system.

Based on this analysis, it was determined that the Read Interceptor could convey flow generated by the target (coincidental) interior storm event during a high river condition down to the Read CSO Station site. The approximate size of the flood pumping station would be about 60 MGD. This analysis assumed that all of the flow upstream of Beaver Brook would be pumped into the river during a coincidental larger rain event and an extreme high river condition and Read CSO Station flow would continue to Duck Island by gravity. Duck Island WWTF wet weather treatment capacity would still be maximized either with downstream north bank interceptor flow or flow from the south bank interceptor system.

The advantage to siting the flood control pump station at the Read site is that it could also be used to convey flow into a future CSO treatment facility. Since a pump station would be required if a CSO treatment system were constructed at the Read site, LRWU recognized the opportunity to utilize the pump station as a dual-use facility for both flood pumping and CSO treatment pumping. This is also beneficial because the pump station would be used more frequently during many storm events in a single year instead of only during river flood conditions, which provides more consistent operating and maintenance activities and operator confidence in operations. Figure 7-5 shows a conceptual plan of the proposed pump station on the Read Site.

LRWWU intends to construct the Read Interceptor Control Structure and the Read Flood Pump Station as one project. LRWWU has budgeted about \$17 million for the project including 20 percent engineering and contingencies. It is estimated that the Read Interceptor Control Structure will reduce annual CSO discharges by about 9 MG per year.

7.7.2 Future CSO Treatment Facilities at the Read Site

During the Phase 1 LTCP and the evaluations of the flood pump station locations, LRWWU considered the need for future satellite treatment facilities to meet the eventual CSO reduction goals. Potential expansion of wet weather treatment capacity at the Duck Island WWTF was considered first but LRWWU identified some concerns with reserving the remaining land available at the site for CSO treatment when there may be also be a need for future process improvements to meet potentially more stringent NPDES effluent limits.

Accordingly, LRWWU identified the Read CSO site as a potential site that could support a future CSO treatment facility and be integrated with the required flood pumping station. This site is also close to the Duck Island facility (1/2 mile), making this satellite site easier to operate and maintain. Based on current available information, a conceptual siting analysis showed that a 60 MGD wet-weather treatment facility could be constructed in the remaining land available after the Read Interceptor Control Structure and Read Flood Pump Station were constructed. The wet-weather treatment facility would provide the maximum available treatment capacity within a limited footprint. The flood pumping station would be beneficial to convey flow to the near surface to avoid subgrade treatment facilities. Figure 7-5 shows the conceptual layout of the three proposed LRWWU facilities on the Read Site.

The Read CSO Treatment facility will be considered in LRWWU's Phase 3 CSO LTCP program. During the development of the Read Flood Pumping Station, LRWWU will consider further the dimensions required for the future CSO facility and ensure that the design of the site incorporates all elements so that there is an integrated approach for CSO control at the site.

7.8 Interim System Characterization

In between the completion of the Phase 2 program and the beginning of the Phase 3 program, LRWWU intends to conduct flow monitoring and complete further system characterization over a twelve-month period. This system characterization period will allow LRWWU to identify the CSO reduction benefits it achieved in the Phase 2 program and modify its plan for Phase 3 to maximize further CSO reduction.

7.9 Phase 3 Planning

7.9.1 Overview

As noted above, LRWWU is committing to an investment of \$71 million for an integrated LTCP-CIP Phase 3 program, which will extend over five years. The Phase 3 program will begin in 2020, after the Interim System Characterization is completed. LRWWU will finalize the Phase 3 projects and submit an implementation plan to the agencies through a CSO Phase 3 LTCP report in December 2019.

7.9.2 LTCP-CIP Planning and Sewer Rehabilitation and Stormwater Management

As shown in Table 7-2, elements of the Phase 3 projects will incorporate ongoing programs adopted in Phase 2, including Capital/LTCP Planning and Assessment, Stormwater Management, and Sewer Rehabilitation. These programs will be funded at similar rates as the Phase 2 projects.

There are several other planned large capital projects aimed primarily at CSO control and surcharge relief, as discussed below. LRWWU has not defined budgets for these projects, but will further refine the scope and costs of this work during the Phase 2 program.

7.9.3 South Bank CSO Control

In Phase 2 and Phase 3, LRWWU intends to focus on CSO control on the North Bank – at Walker, Beaver Brook, West, and Read stations. Subsequent to Phase 3, plans will be refined to address CSO discharges at Tilden, Warren, Barasford, and Merrimack stations. For Tilden CSO Station, the primary control option will likely be separation of upstream combined sewer system or green infrastructure.

For the Warren and Merrimack Stations, the primary options likely entail more conveyance capacity to bring flows downstream to the Duck Island WWTF (with expanded wet weather treatment capacity) including new siphons at Warren CSO Station and one along the Merrimack West Interceptor (to convey more flow to the WWTF). In addition, depending on the relative performance of LRWWU Green Infrastructure demonstration project and public acceptance, LRWWU may incorporate more stormwater infiltration technologies system- or basin-wide to avoid reliance on satellite storage or treatment facilities.

As noted above, based on the concerns listed in Section 7.1, LRWWU intends to utilize an adaptive management approach to the LTCP development and implementation. Especially considering LRWWU concerns about the SWMM model predictive capacity (based on the limited data obtained during the 2013 flow monitoring program), the phased approach allows LRWWU to obtain additional field verification of the model results before further phases of a costly control program are adopted.

7.9.4 WWTF and Pump Station Improvements

This program is focused on continuing improvements at the Duck Island facility to replace aging equipment, continue process and safety improvements, and electrical and mechanical upgrades according to the CIP. In addition, LRWWU will upgrade aging sewer pumping stations to increase its maintenance efficiencies and ensure reliability.

7.9.5 Wet Weather Treatment

Read Station Wet Weather Treatment Facility

The Read Wet Weather Treatment Facility (Section 7.7.1.3) will provide about 60 mgd of wet weather capacity to treat North Bank interceptor flow. A preliminary design will be completed to determine the best treatment technology to be applied at this site considering the limited land availability.

7.9.6 Combined Sewer System Improvements

Beaver Brook Siphon

Beaver Station siphons (across Beaver Brook) will be expanded to convey wet-weather flows to the planned Read CSO treatment facility. With the Read treatment facility and increased conveyance, CSO

discharges along the North Bank Interceptor will be reduced significantly. The extent of this control, and its impact on South Bank conveyance, will be analyzed once the Read facility is online.

Tilden Area Sewer Separation

LRWWU will continue to implement project to separate portions of the Acre neighborhood in Lowell, upstream of the Tilden CSO Station, to further reduce CSO discharges from Tilden Station.

Stormwater Infiltration

LRWWU will continue to implement infiltration projects that further its goal of increasing public acceptance and awareness of green infrastructure improvements. In addition, LRWWU will define the role of green infrastructure in its ultimate plan for CSO control.

7.9.7 Wet Weather Storage

As part of the Phase 3 Plan, LRWWU has identified three areas of the system that will benefit from local wet weather flow storage facilities to reduce sewer surcharging and CSO discharges. These storage facilities will address surcharge problems identified previously along the Marginal/Middlesex Interceptor, in the Douglas Road/Wentworth Avenue area, and at Walker Station.

LRWWU acknowledges that there may not be adequate funding in Phase 2 to eliminate adverse system surcharge along the Middlesex Interceptor at Pevey Street and at the Boys & Girls Club. Thus, LRWWU is committing additional Phase 3 monies to complete the improvements to eliminate surcharging in the corridor. The Douglas Road surcharging problems and potential solutions are discussed further in Section 7.8.1.6.

During Phase 3, LRWWU will identify potential projects to control CSOs along the South Bank Interceptor. As part of the development of this report, LRWWU investigated alternatives to implement further control of the Tilden, Warren, and Merrimack CSO Stations. Site limitations near these facilities require consideration of more challenging and costly system improvements.

7.9.8 Wentworth Avenue/Douglas Road Area Surcharge Relief

The Wentworth Avenue and Douglas Road area is located along the upstream portion of the Barasford Interceptor where the interceptor size ranges from 24-inches to 36-inches. The Wentworth area is upstream of the Douglas Road area. The tributary area is partially combined with separated areas discharging to a surface drainage system, which leads to Trull Brook, with limited conveyance capacity. Currently, there are known surface flooding issues at the Phoenix Avenue wetlands bordering Wentworth Avenue and at the Alcott Street Wetlands along Trull Brook. In addition, residents along Wentworth Avenue and Douglas Road have experienced sewer backups into basements. Some of the residents along Douglas Road have installed backflow valves to mitigate the situation until a solution is developed by the city.

Sewer Separation Alternatives

Sewer separation of portions of the area upstream of the Douglas Road area was considered to alleviate the surcharge problems. One issue with sewer separation in this basin is that the surface drainage system is already over capacity and, as noted above, there are already surface water issues with the wetlands and brooks in the area. Accordingly, adding more drainage flow via sewer separation projects to mitigate sewer surcharging would only exacerbate the surface flooding. LRWWU evaluated alternatives to increase drainage system capacity in Lowell but this may create surface flooding problems at the Tewksbury town line, along Trull Brook.

Pipe Replacement

In order to significantly reduce surcharging and surface flooding at the 5 year design storm at Wentworth Avenue, Rogers Street and Douglas Road by increasing sewer flow conveyance, the existing system would need to be replaced with a 36" pipe in Wentworth Avenue and Rogers Street and a 60" pipe in Douglas Road (according to the current model). However, this sewer would need to be replaced for a distance of nearly two miles. Due to the magnitude of costs for this option, replacement alternatives were not considered further.

Parallel Sewers and Storage Facilities

In order to significantly reduce surcharging and surface flooding at Wentworth Avenue, Rogers Street, and Douglas Road without sewer separation, the current hydraulic modeling suggests that a parallel 48-inch diameter pipe (1,200 feet) from Wentworth Avenue to Rogers Street, 6 MG storage tank at stadium parking lot on Douglas Road (with 1 foot offset to tank), pipe upsizing to 36" on Wentworth Avenue (380 feet) and to 60-inch diameter on Douglas Road (990 feet) would be required.

Additionally, a parallel conveyance pipe could be routed cross-country from Wentworth Avenue to the existing Douglas Road sewer. Flow from this sewer could be conveyed into a storage facility at the stadium. This alternative includes a great amount of large diameter parallel sewers and a large storage facility to be used intermittently. Figure 7-6 shows some of these alternatives.

By including sewer separation, the parallel and offline storage facilities size could be greatly reduced. However, this approach would resolve a sewer surcharging problem while exacerbating surface flooding issues in this area. For this reason, it is preferred to phase a plan that focuses on storage so that the sewer and stormwater issues can be monitored and balanced as projects are constructed. Level monitoring of the local sewer system will characterize the extent of surcharging and inform the sizing and placement of conveyance and storage facilities.

7.10 Summary

As discussed above, LRWWU has adopted an adaptive management strategy to implement its integrated CSO reduction plan to address CSO discharges, stormwater management, sewer system and treatment plant performance, and wet weather flow storage and treatment. This approach was used to great success in the Phase 1 LTCP program. LRWWU believes that the proposed plan – a \$123 million investment implemented in two phase over the next eleven years – demonstrates a commitment to its dual mission of providing cost-effective water transport and treatment services while protecting water quality in the Merrimack River watershed. Please refer to Table 7-1 for a summary of the CSO Phase 2 LTCP program and to Table 7-2 for a summary of the CSO Phase 3 LTCP program.